MDOT RC-1514

Research

Combining Link Slab, Deck Sliding over Backwall, and Revising Bearings

FINAL REPORT – AUGUST 2008
(APPENDICES)

Western Michigan University
Department of Civil & Construction Engineering
College of Engineering and Applied Sciences

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COMBINING LINK SLAB, DECK SLIDING OVER BACKWALL, AND REVISING BEARINGS

(Appendices)

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Submitted to:

MDOT

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APPENDIX A

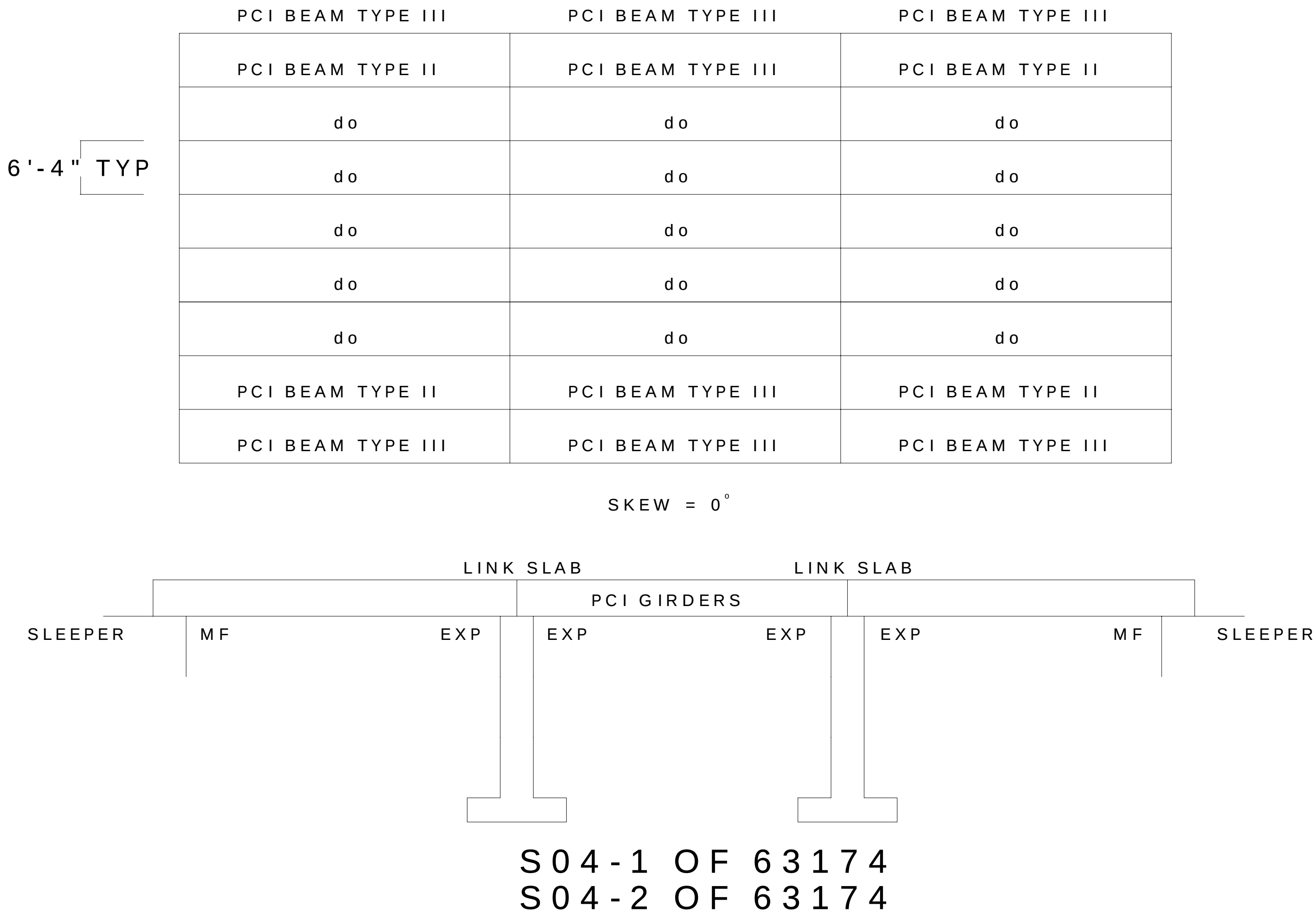


Figure A-1. Plan and elevation of S04-1, 2 of 63174

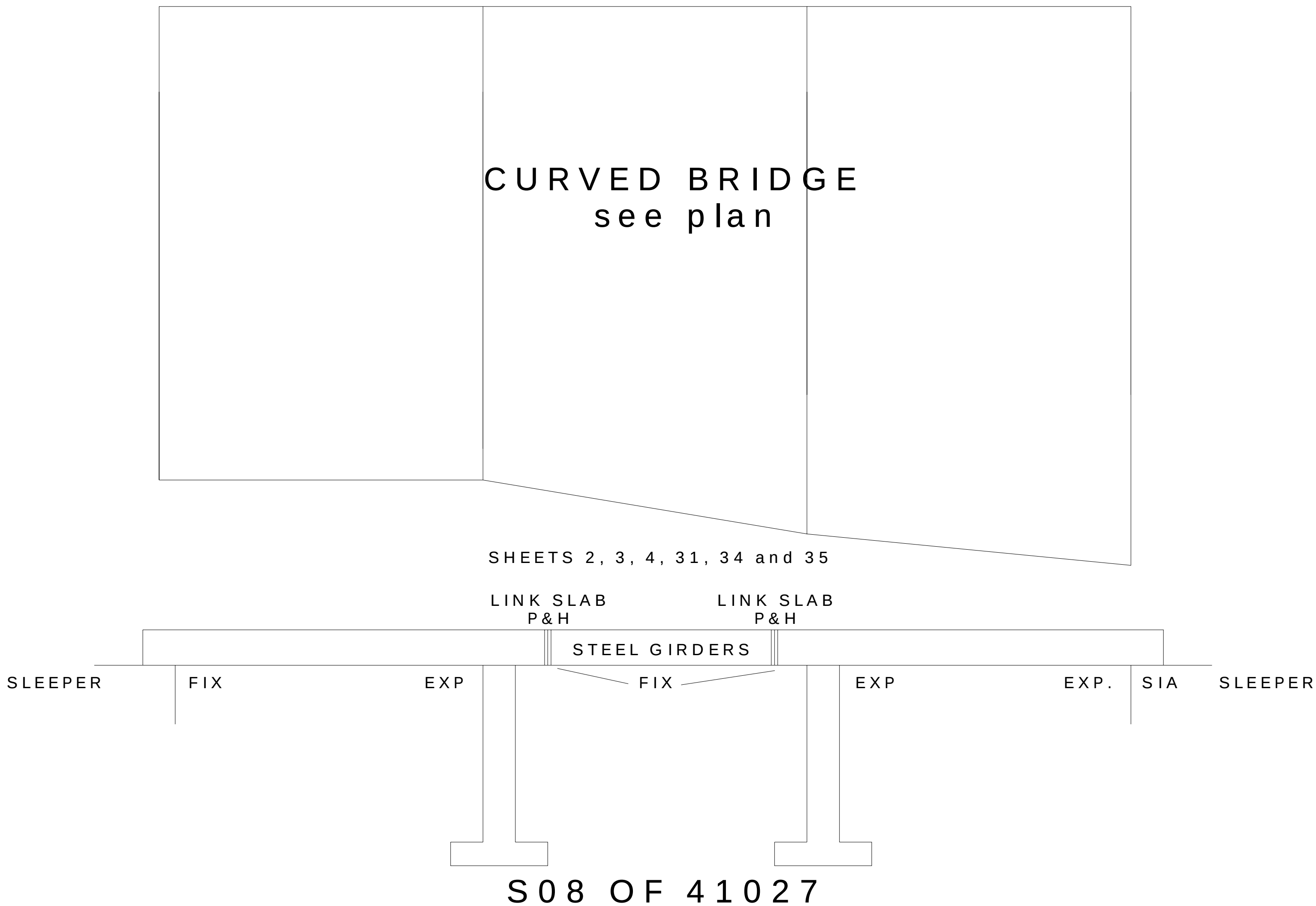


Figure A-2. Plan and elevation of S08 of 41027

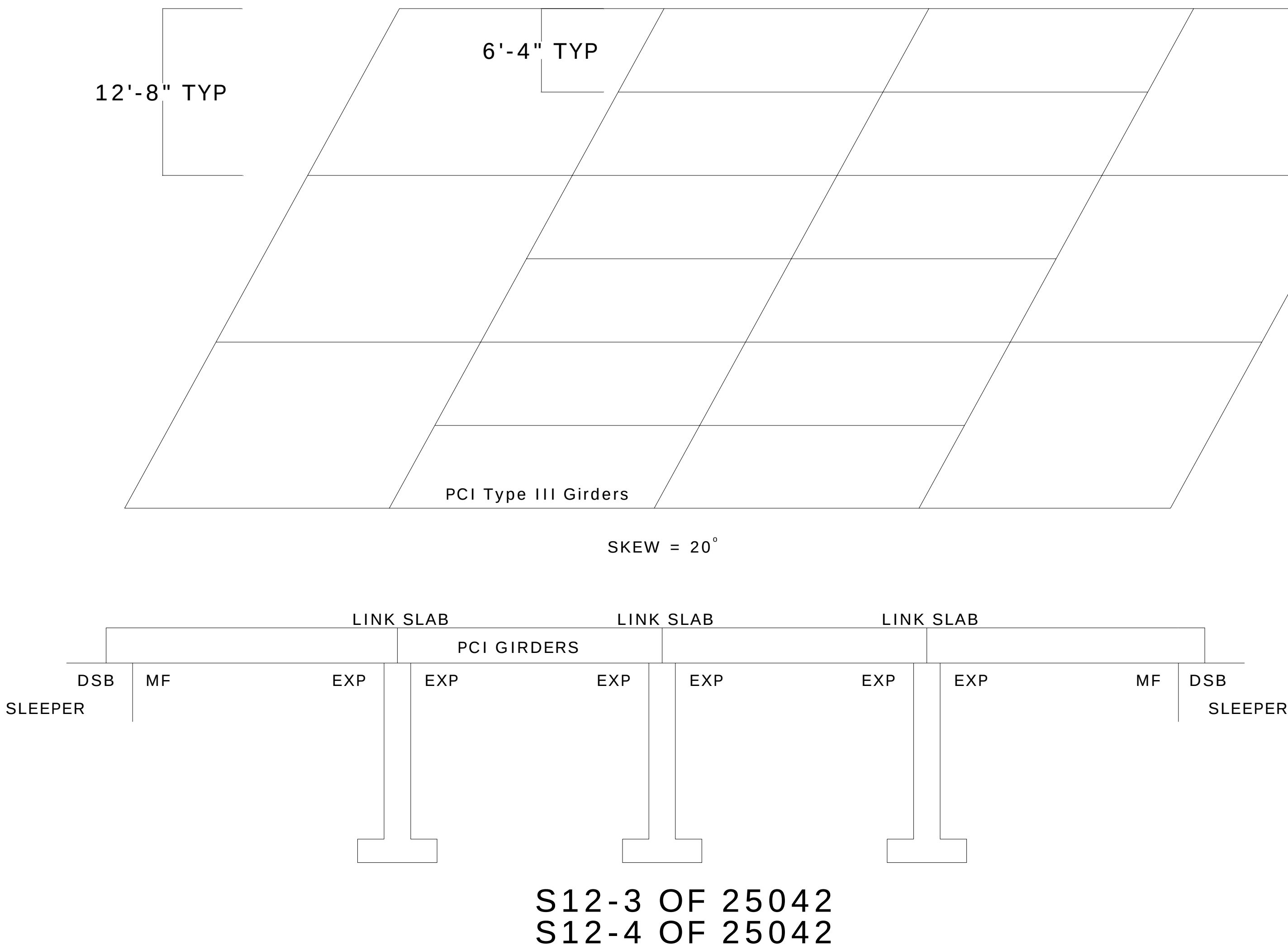


Figure A-3. Plan and elevation of S12-3 and 4 of 25042

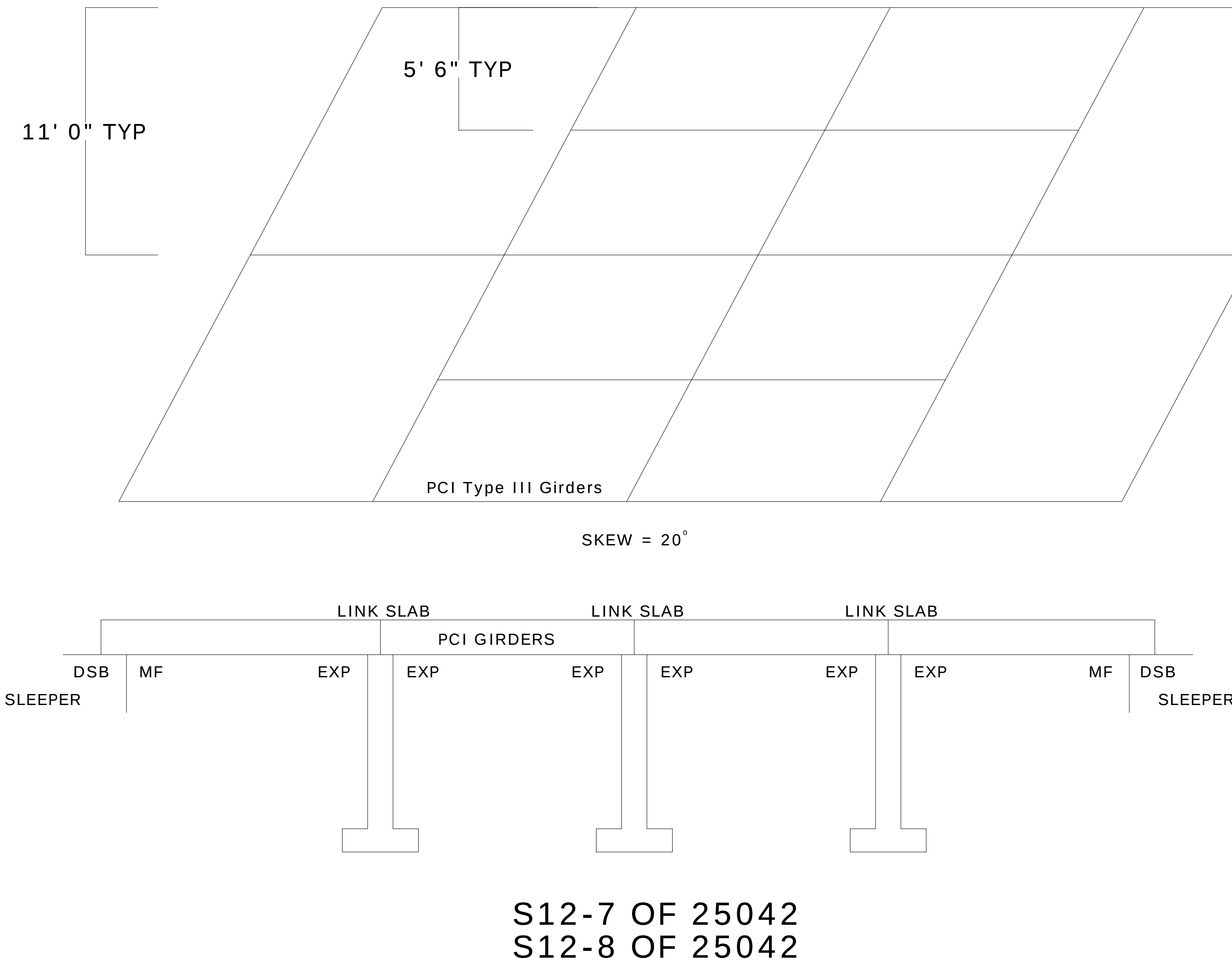


Figure A-4. Plan and elevation of S12-7 and 8 of 25042

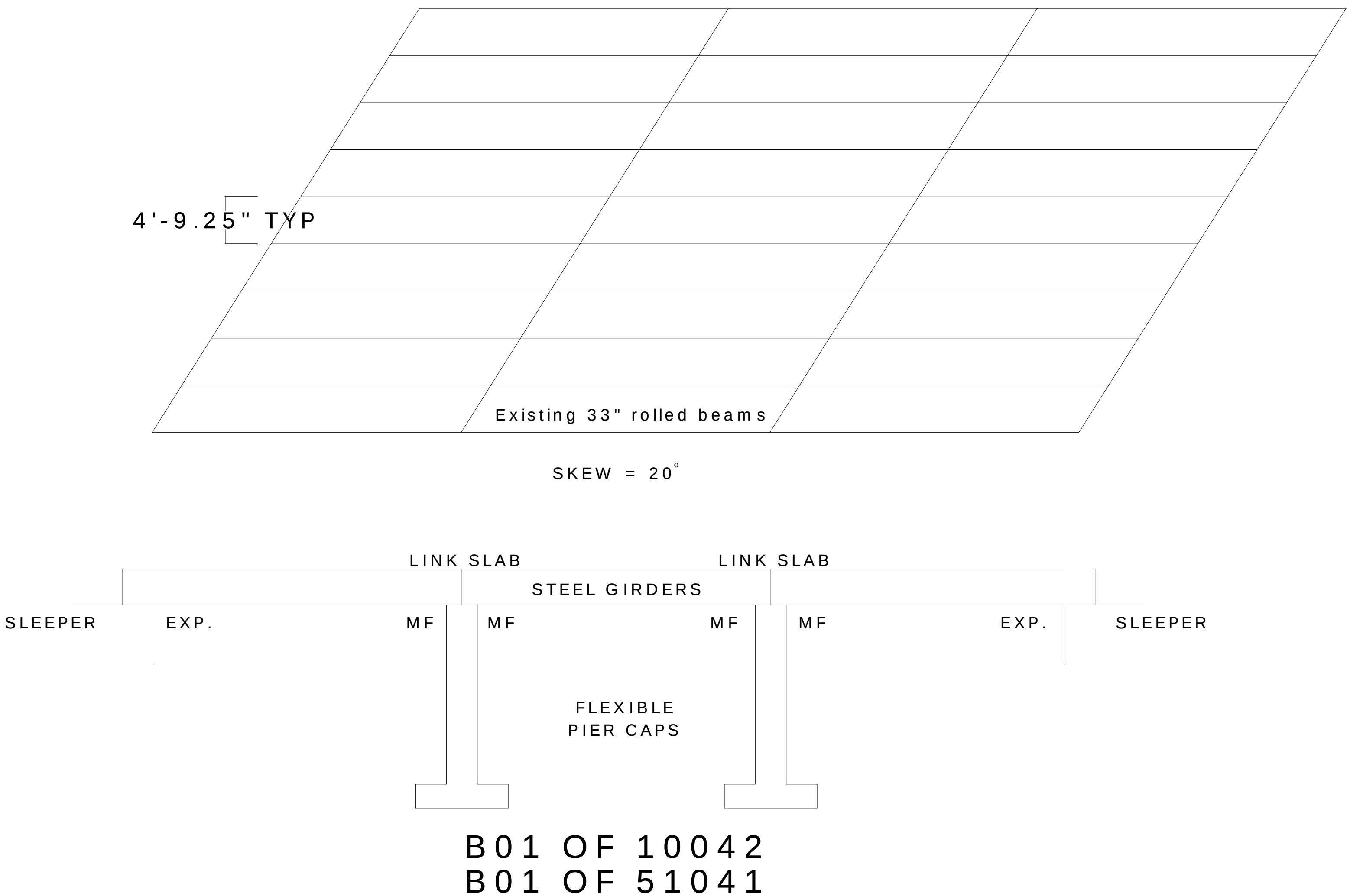


Figure A-5. Plan and elevation of B01 of 10042 and B01 of 51041

APPENDIX B

Field inspection data of the following bridges

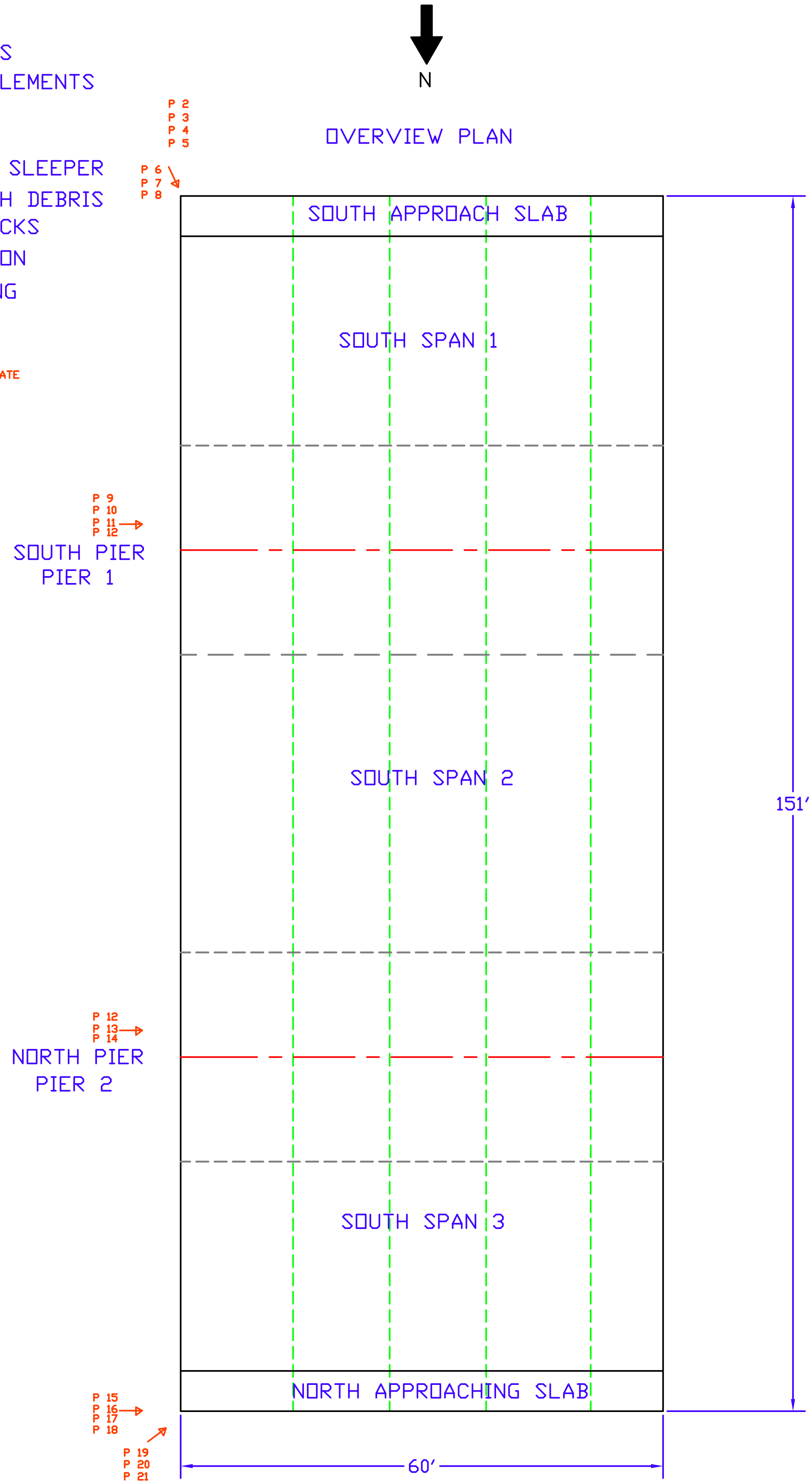
No	Bridge ID	Description	Inspection Date	Remarks
1	S04-1-63174	I-75 NB over 13 Mile Rd	12/03/2006	Detailed inspection
2	S04-2-63174	I-75 SB over 13 Mile Rd	12/03/2006	Photo log
3	S08-41027	I-196 EB over Monroe Av	11/04/2006	Detailed inspection
4	B01-10042	M115 over Betsie Rive	11/04/200	Detailed inspection
5	S12-3-25042	I-69 EB over I-75	11/05/2006	Detailed underside inspection
6	S12-4-25042	I-69 WB over I-75	11/05/2006	Detailed inspection
7	S12-7-25042	I-69 EB Ramp over I-75	11/05/2006	Detailed inspection
8	S12-8-25042	I-69 WB Ramp over I-75	11/05/2006	Detailed inspection

FIELD INSPECTION TEMPLATE

For S04-1 OF 63174 ON I-75 NB OVER 13 MILE ROAD , OAKLAND COUNTY, METRO REGION

**STAY-IN-PLACE FORMS
**NO EROSION OR SETTLEMENTS OF BACKFILL
**P1-BRIDGE PLATE
**EXPANSION JOINTS @ SLEEPER SLABS ARE FILLED WITH DEBRIS AND THEY CONTAIN CRACKS SHOWING THAT EXPANSION JOINTS ARE FUNCTIONING

P 1- BRIDGE PLATE



INSPECTOR:

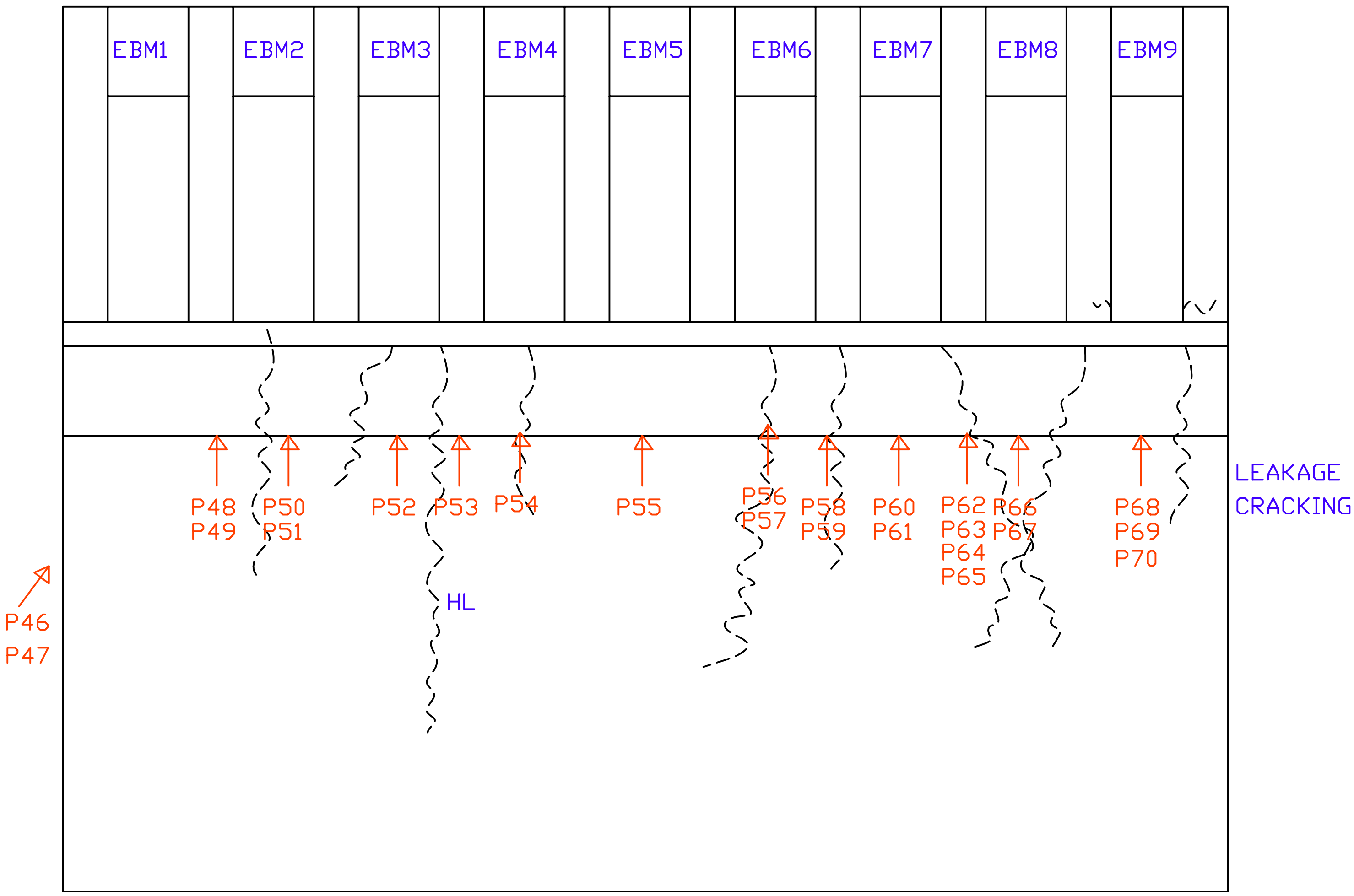
DATE: 12/03/06

PAGE: 1/ 13

FIELD INSPECTION TEMPLATE
Bridge ID: S04-1 of 63174

**north is out of the page.

SOUTH ABUTMENT



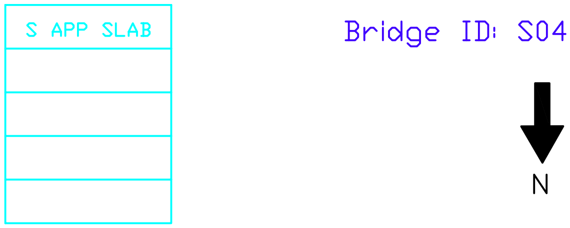
INSPECTOR:

DATE: 12/03/06

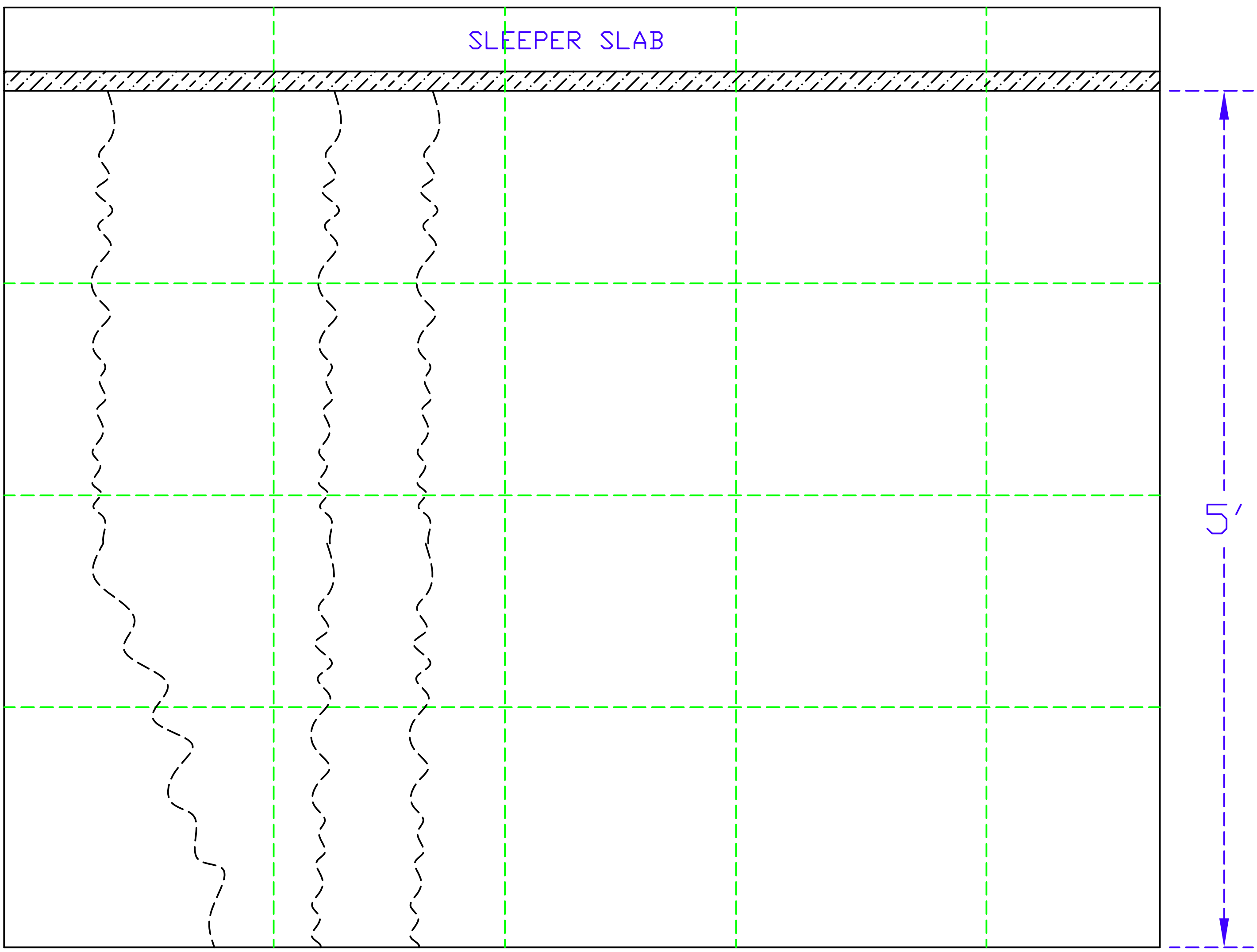
PAGE: 11/13

FIELD INSPECTION TEMPLATE

Bridge ID: S04-1 of 63174



SOUTH APPROACH SLAB



INSPECTOR:

DATE: 12/03/06

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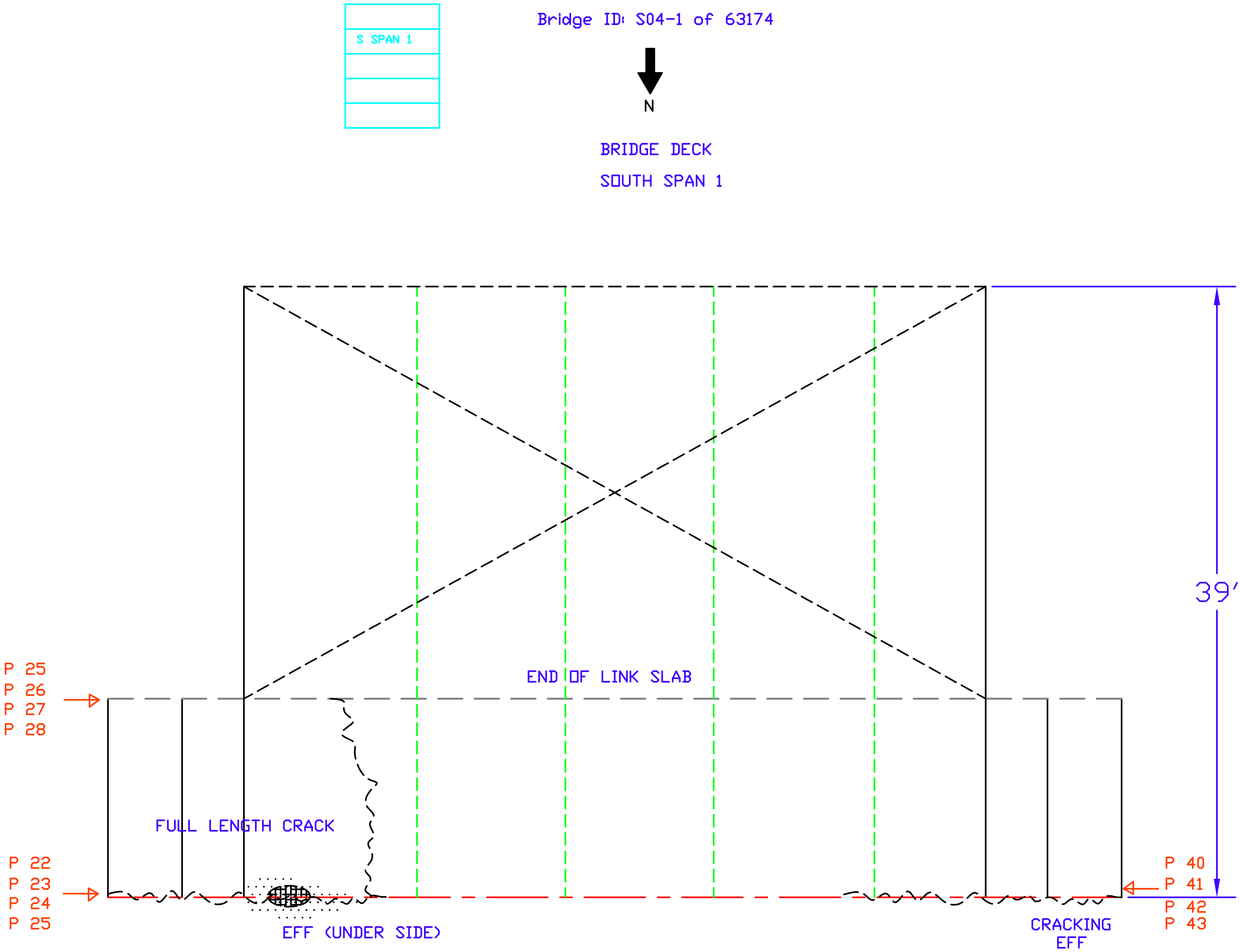
FIELD INSPECTION TEMPLATE
Bridge ID: S04-1 of 63174



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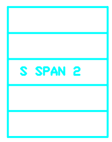
PAGE: 4/13

FIELD INSPECTION TEMPLATE
Bridge ID: S04-1 of 63174



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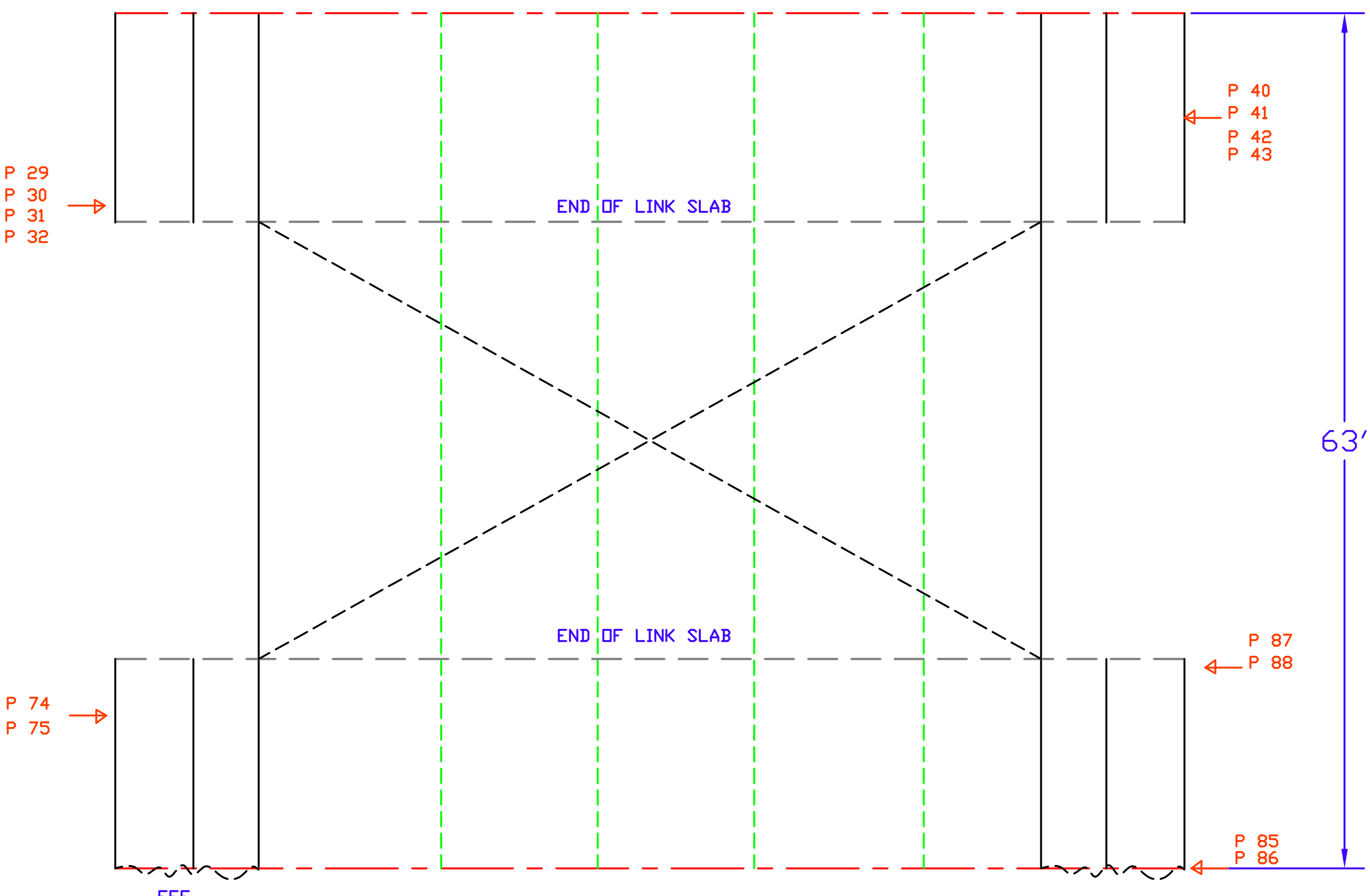
BRIDGE DECK
SOUTH SPAN 2



INSPECTOR:

DATE: 12/03/06

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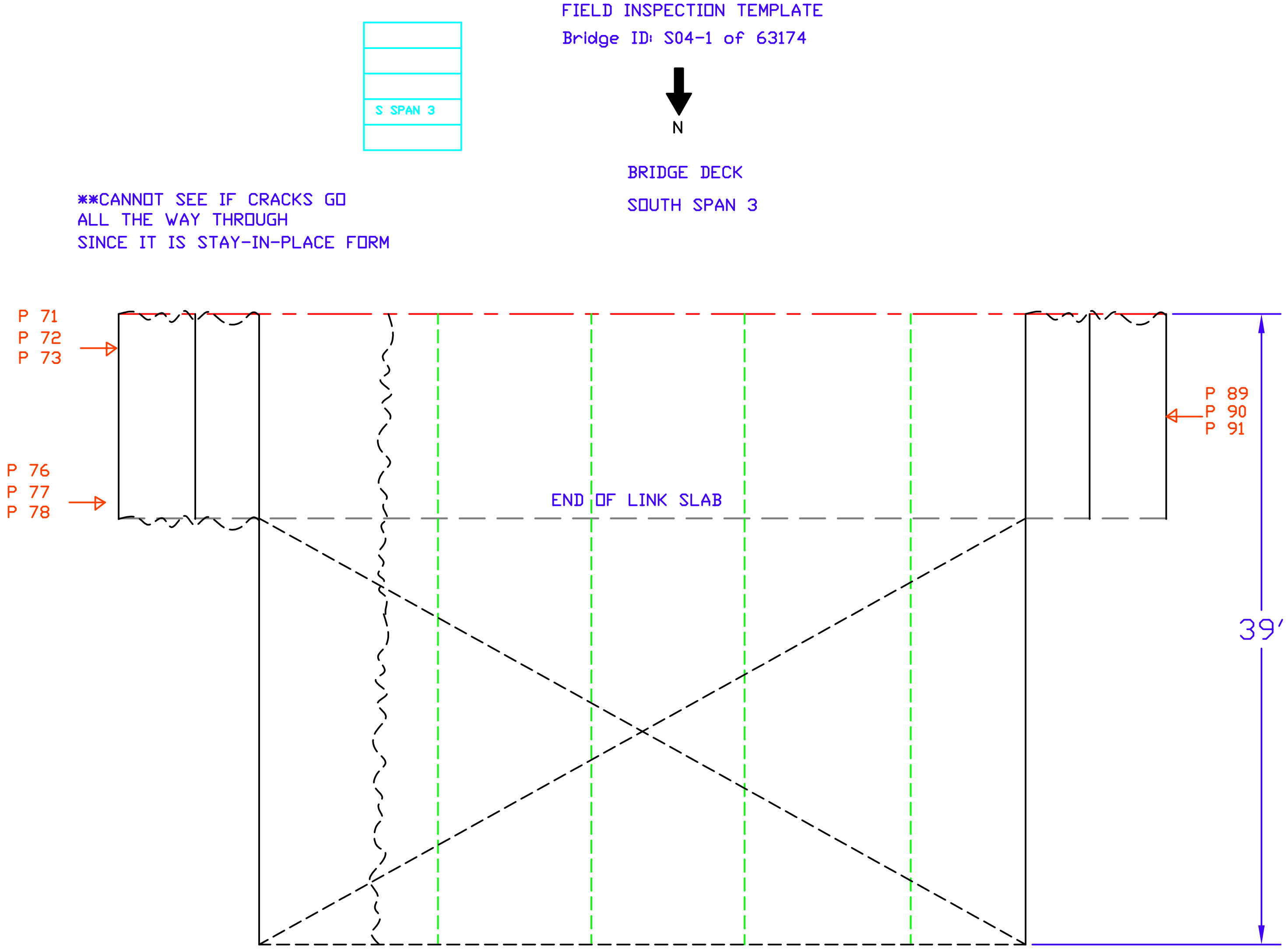
FIELD INSPECTION TEMPLATE

Bridge ID: S04-1 of 63174



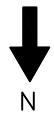
INSPECTOR:

DATE: 12/03/06

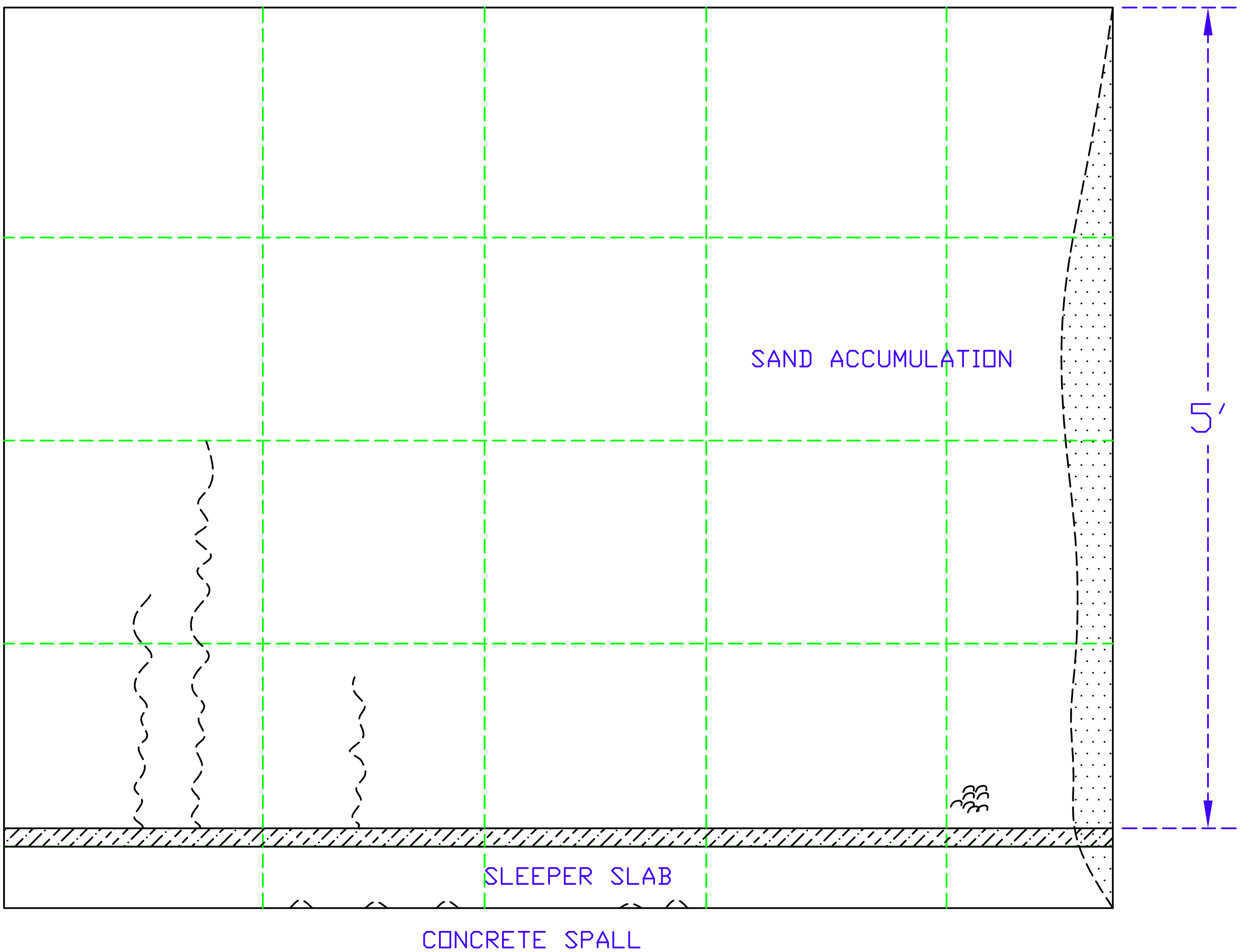
PAGE: 6/13

FIELD INSPECTION TEMPLATE

Bridge ID: S04-1 of 63174



NORTH APPROACH SLAB



INSPECTOR:

DATE: 12/03/06

PAGE: 3/13

FIELD INSPECTION TEMPLATE

Bridge ID: S04-1 of 63174

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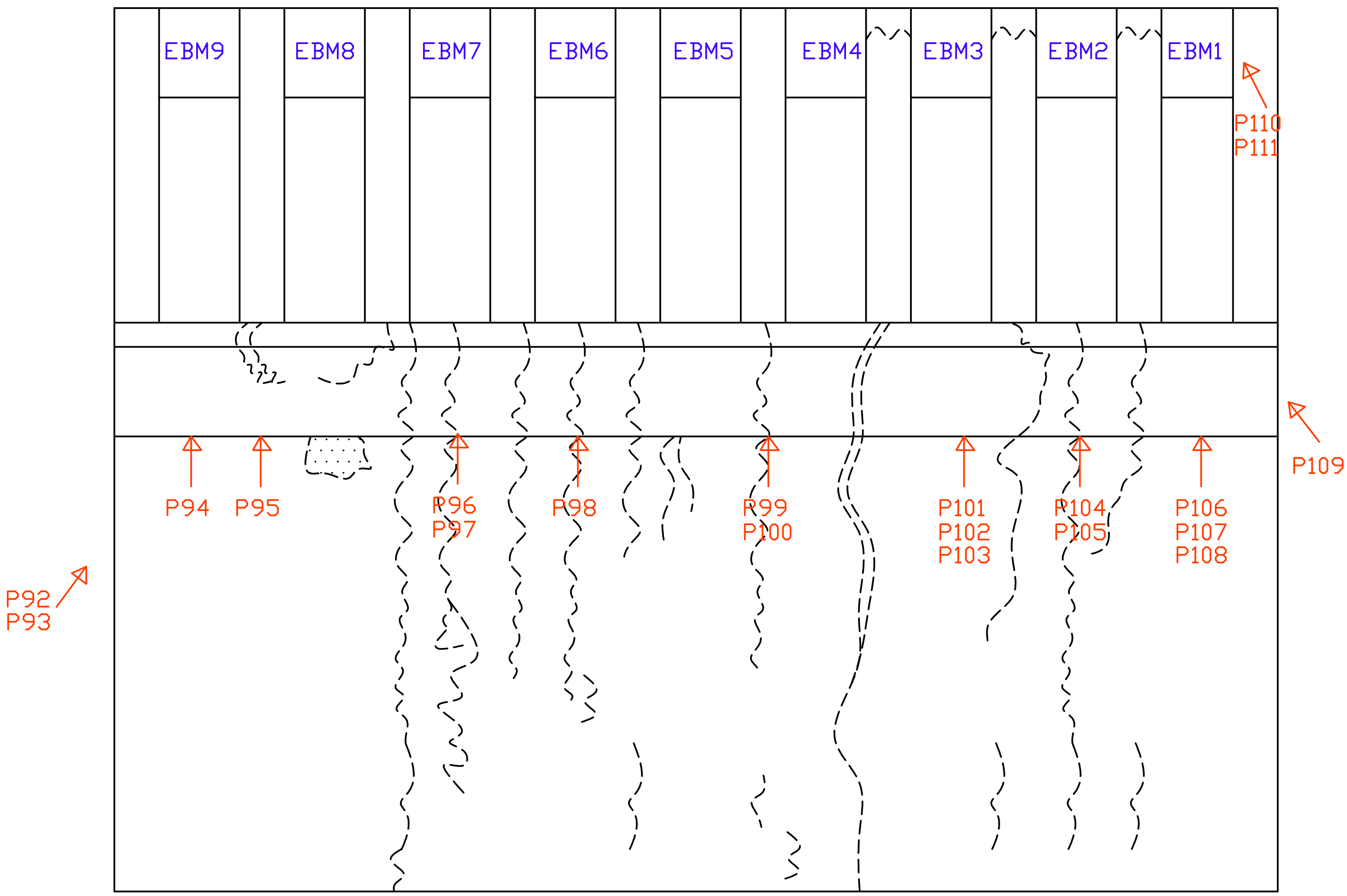
NORTH ABUTMENT



INSPECTOR:

DATE: 12/03/06

PAGE: 10/13

FIELD INSPECTION TEMPLATE

Bridge ID: S04-1 of 63174

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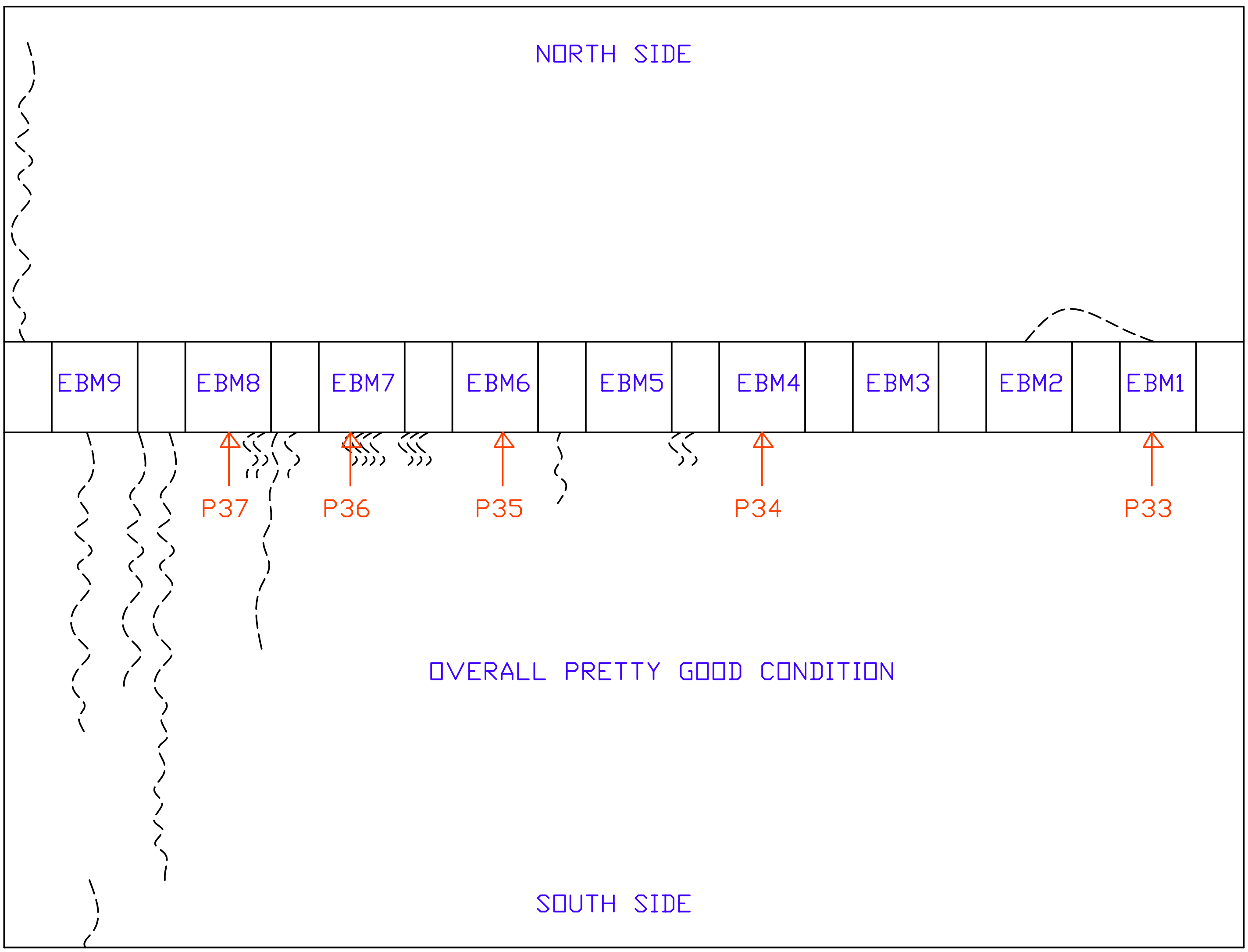
SOUTH PIER (PIER 1)



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DATE: 12/03/06

PAGE: 12/13

FIELD INSPECTION TEMPLATE

Bridge ID: S04-1 of 63174

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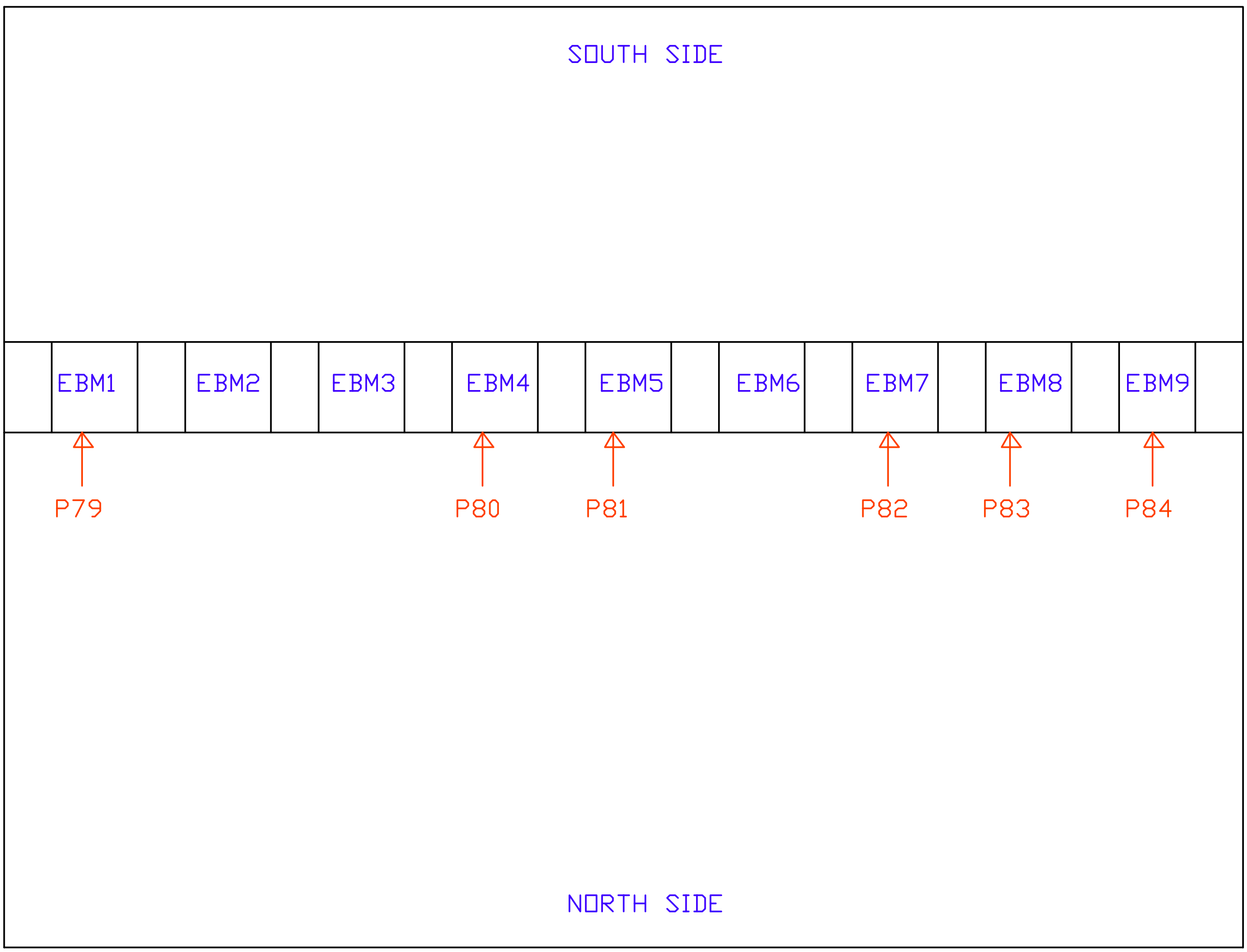
NORTH PIER (PIER 2)



INSPECTOR:

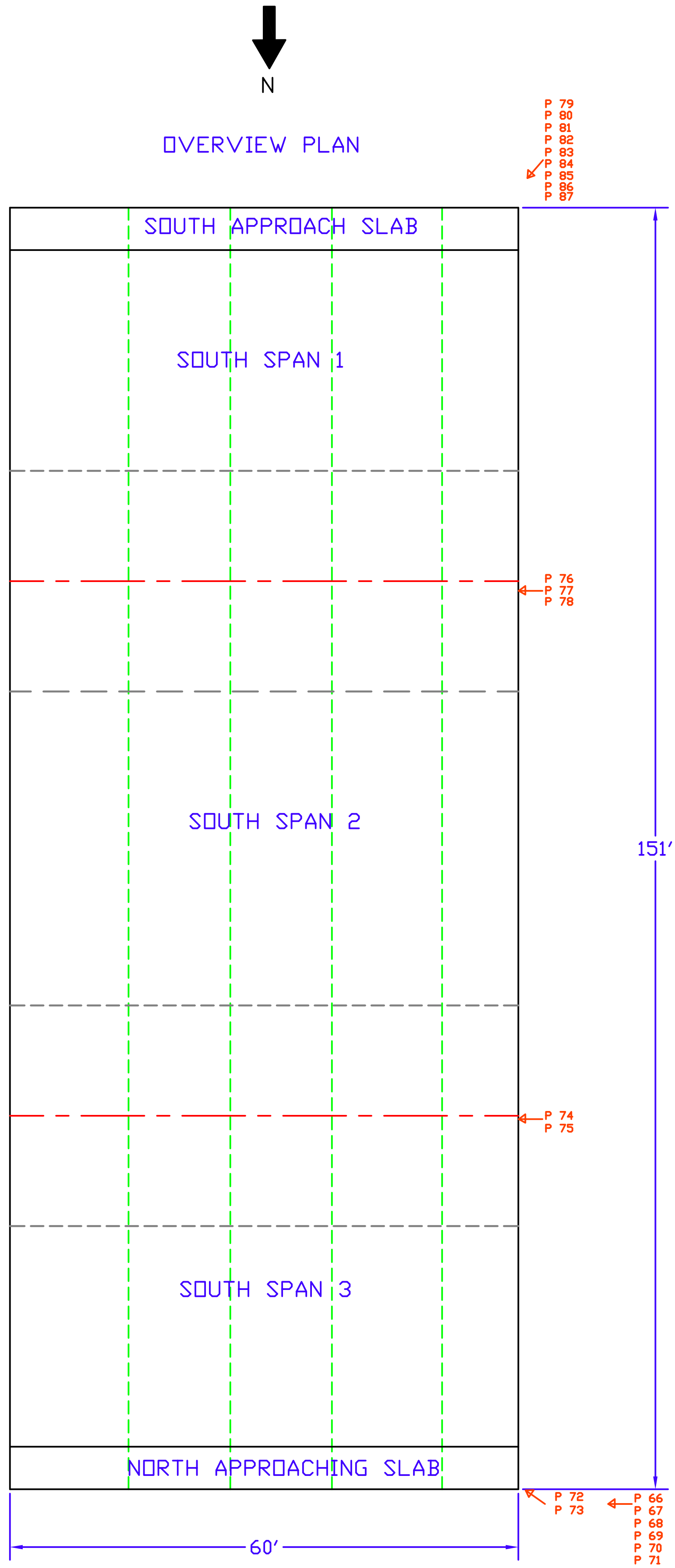
DATE: 12/03/06

PAGE: 13/13

FIELD INSPECTION TEMPLATE

For S04-2 OF 63174 ON I-75 SB OVER 13 MILE ROAD , OAKLAND COUNTY, METRO REGION

**NO SIGNS OF
EROSION OF BACKFILL
**STAY-IN-PLACE FORMS
**EXPANSION JOINTS
AT SLEEPER SLABS
ARE FILLED WITH DEBRIS
**THERE WERE CRACKS
SHOWING THAT JOINTS
WORK
**LINK SLABS SHOWED
NO CRACKING ON TOP



INSPECTOR:

DATE: 12/03/06

PAGE: 1/ 13

FIELD INSPECTION TEMPLATE

Bridge ID: S04-2 of 63174

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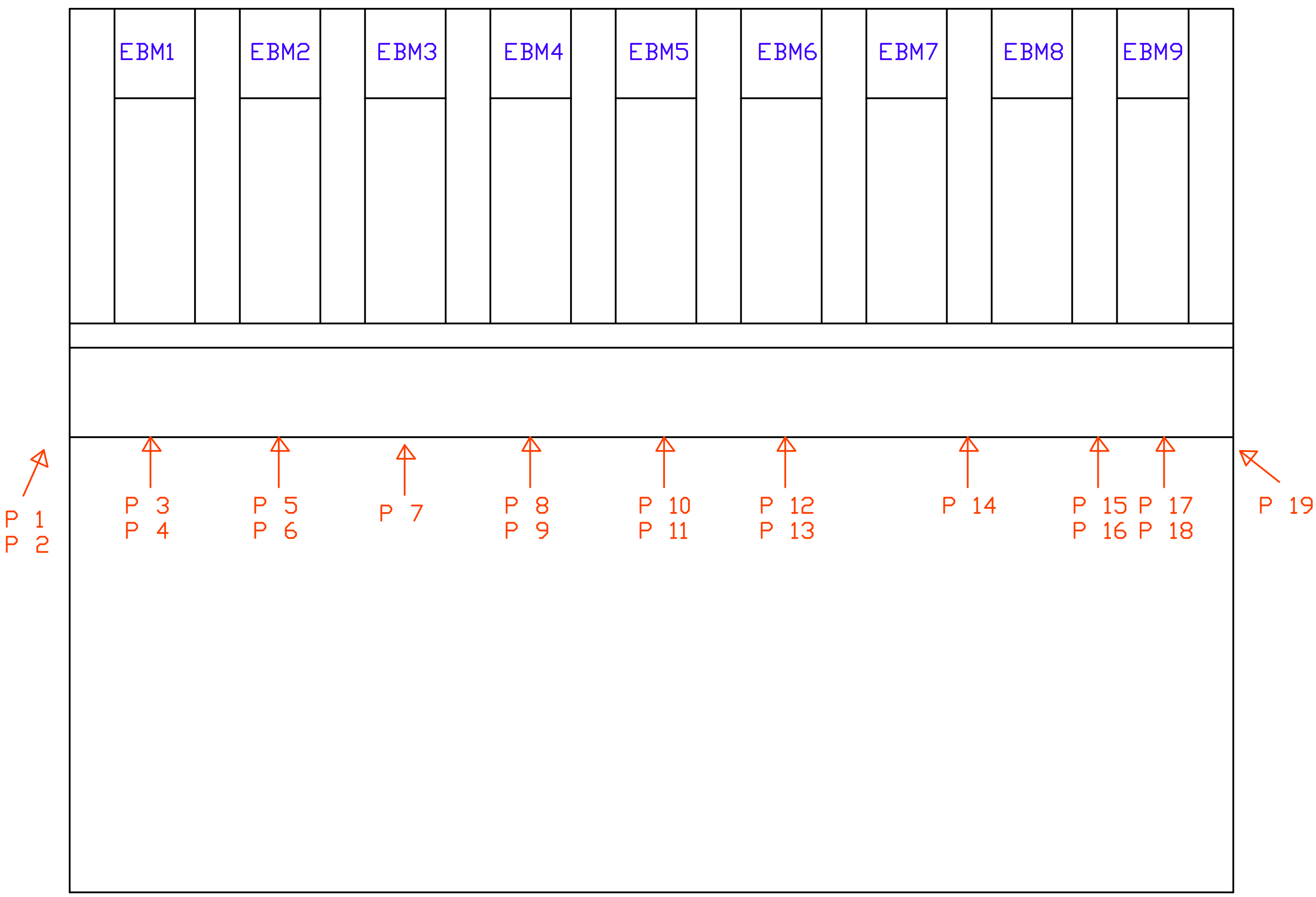
SOUTH ABUTMENT



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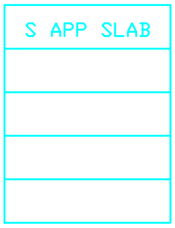
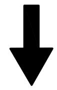
DATE: 12/03/06

PAGE: 11/13



FIELD INSPECTION TEMPLATE

Bridge ID: S04-2 of 63174



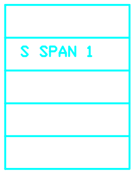
SOUTH APPROACH SLAB

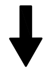
INSPECTOR:

DATE: 12/03/06

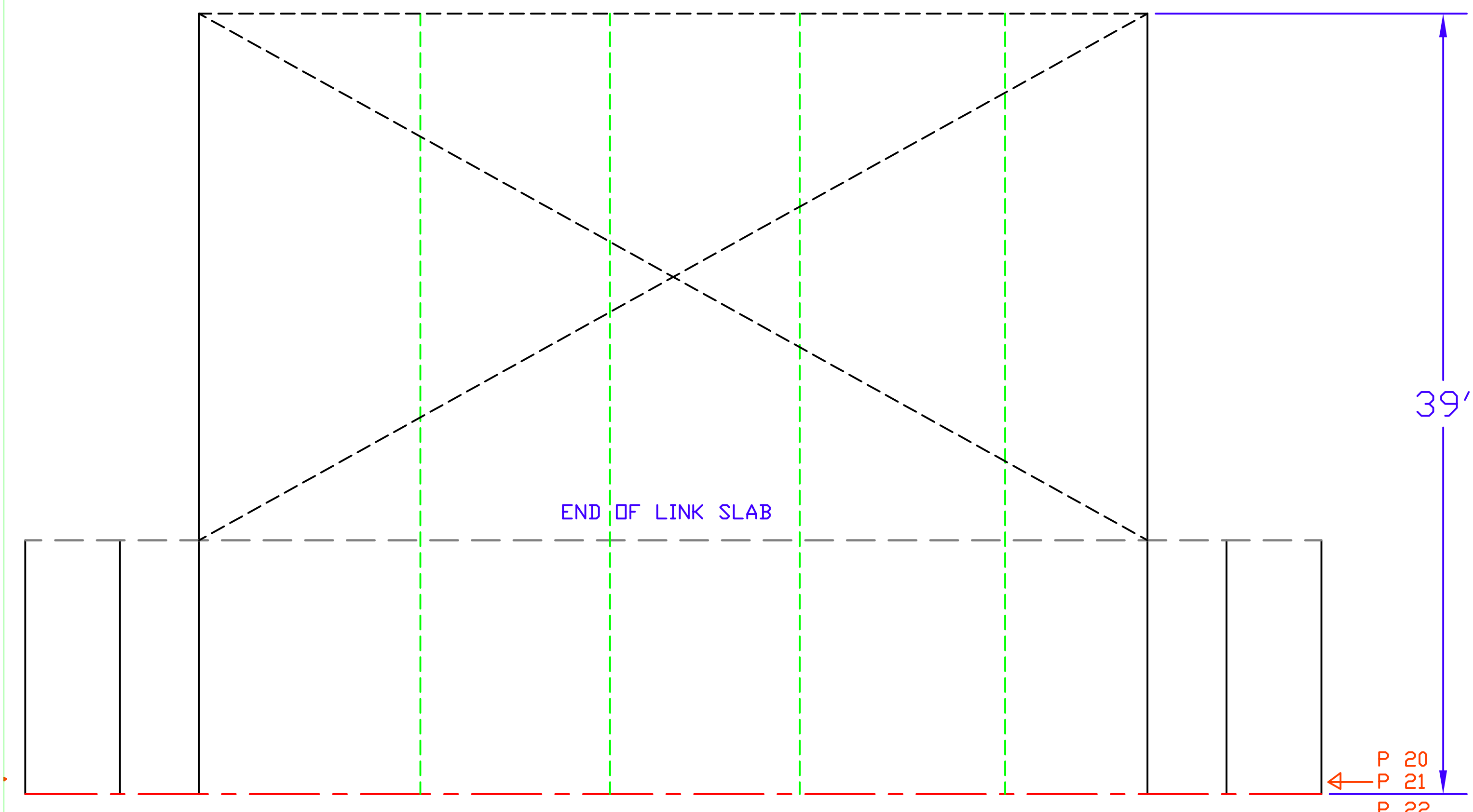
PAGE: 2/13

FIELD INSPECTION TEMPLATE
Bridge ID: S04-2 of 63174





BRIDGE DECK
SOUTH SPAN 1



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DATE: 12/03/06

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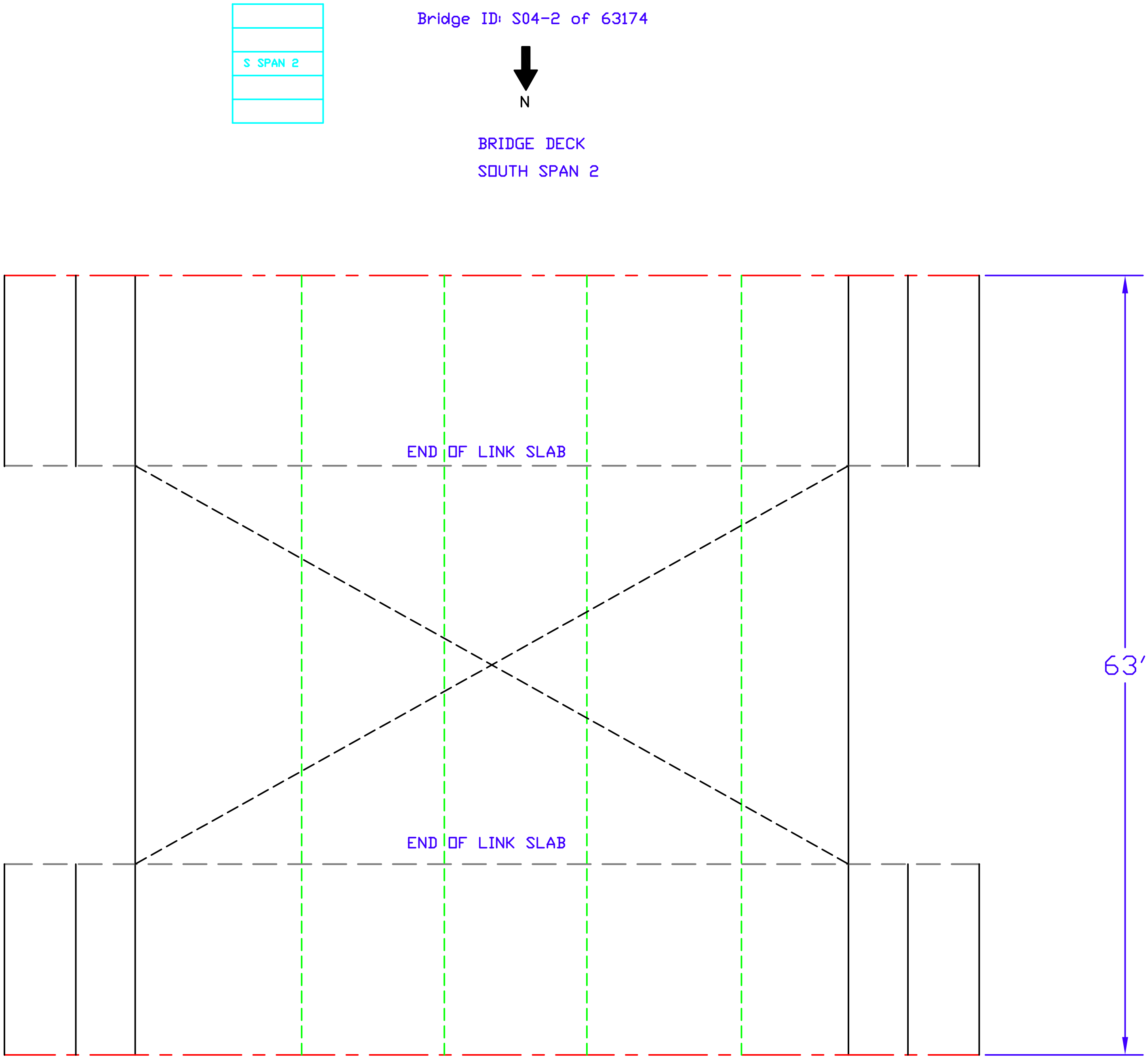
FIELD INSPECTION TEMPLATE
Bridge ID: S04-2 of 63174



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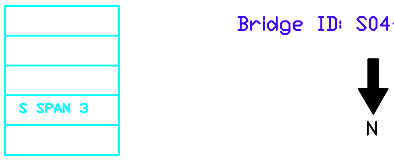
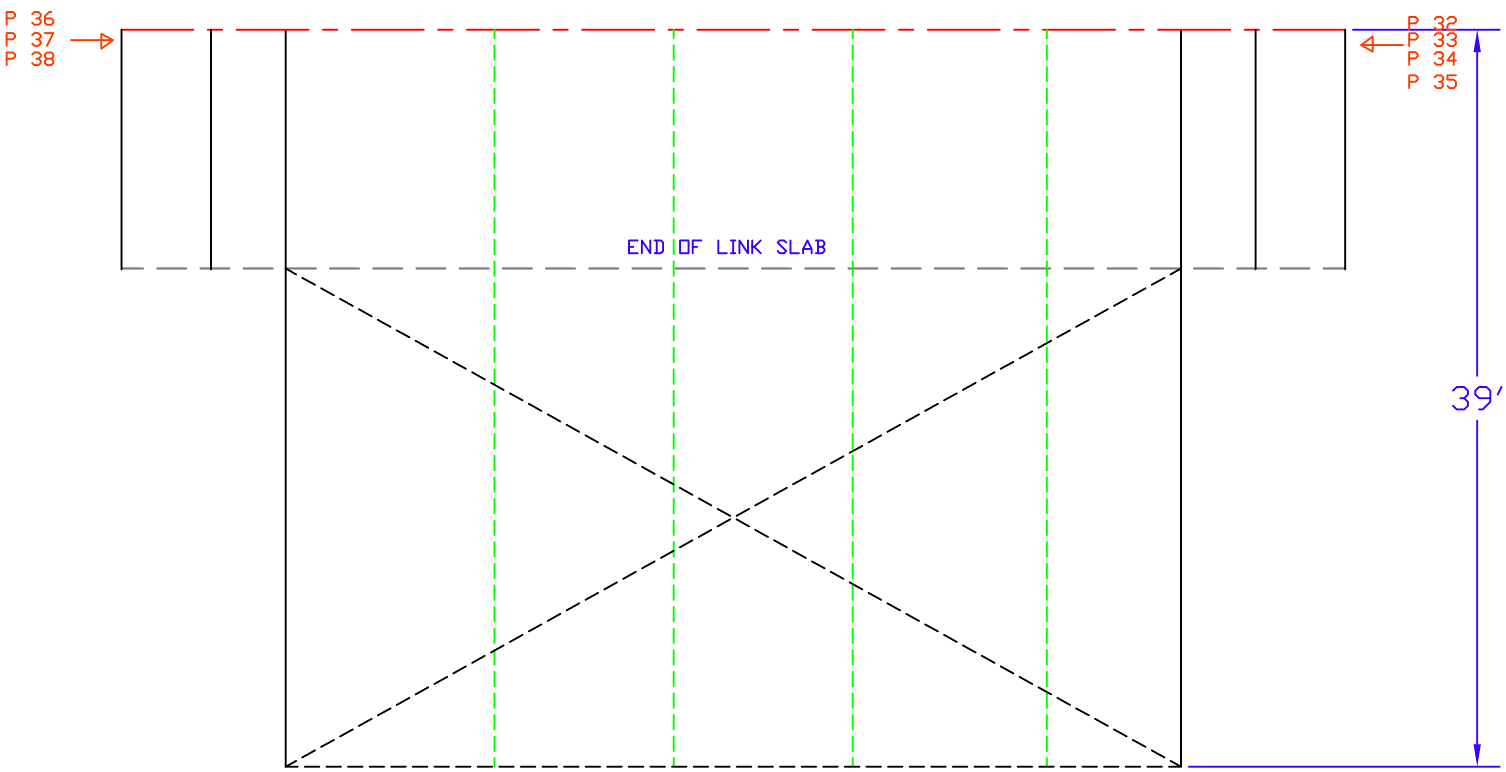
DATE: 12/03/06

PAGE: 5/13

FIELD INSPECTION TEMPLATE
Bridge ID: S04-2 of 63174



BRIDGE DECK
SOUTH SPAN 3



INSPECTOR:

DATE: 12/03/06

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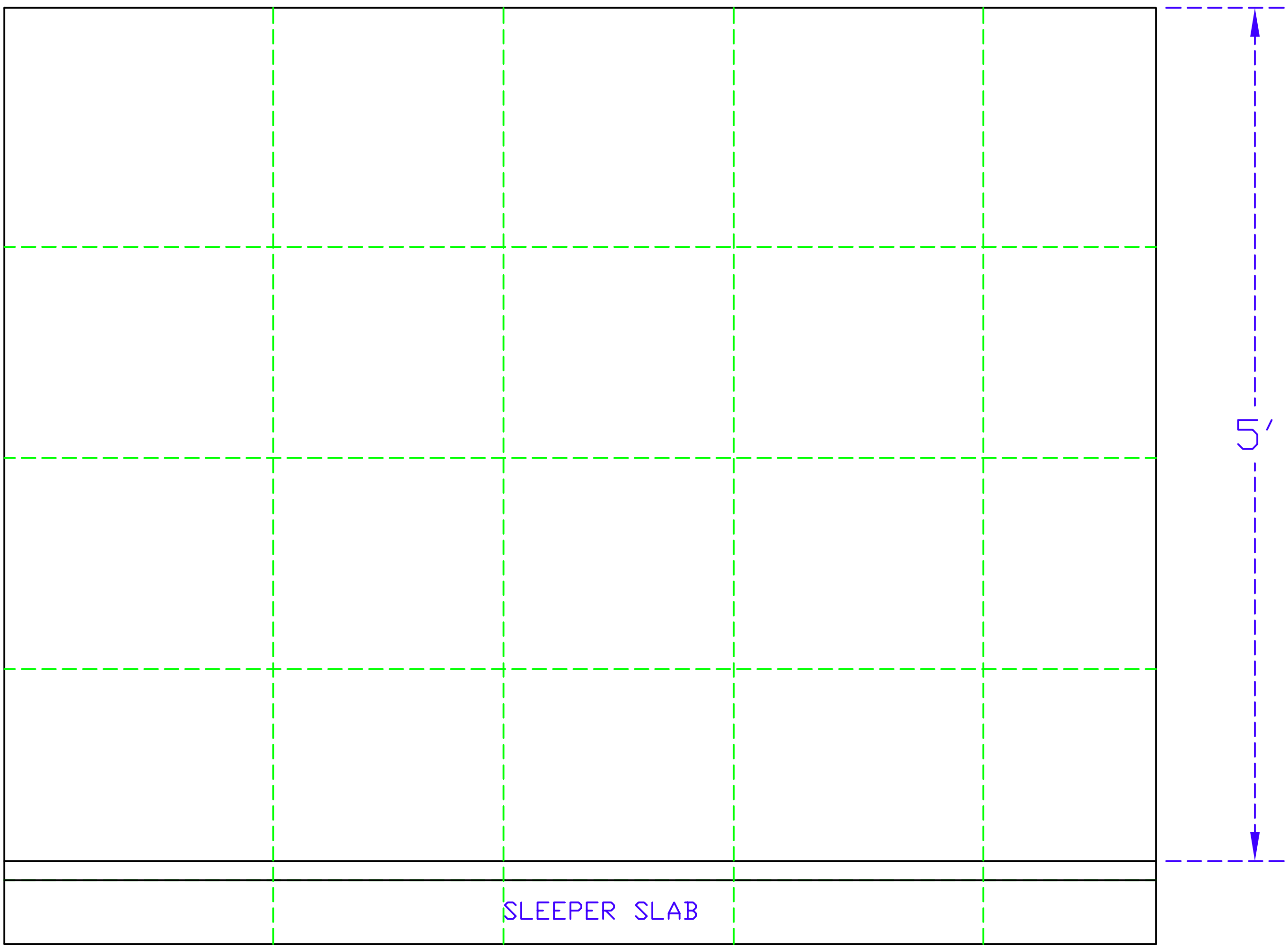
FIELD INSPECTION TEMPLATE

Bridge ID: S04-2 of 63174

N

NORTH APPROACH SLAB



INSPECTOR:

DATE: 12/03/06

PAGE: 3/13

FIELD INSPECTION TEMPLATE
Bridge ID: S04-2 of 63174

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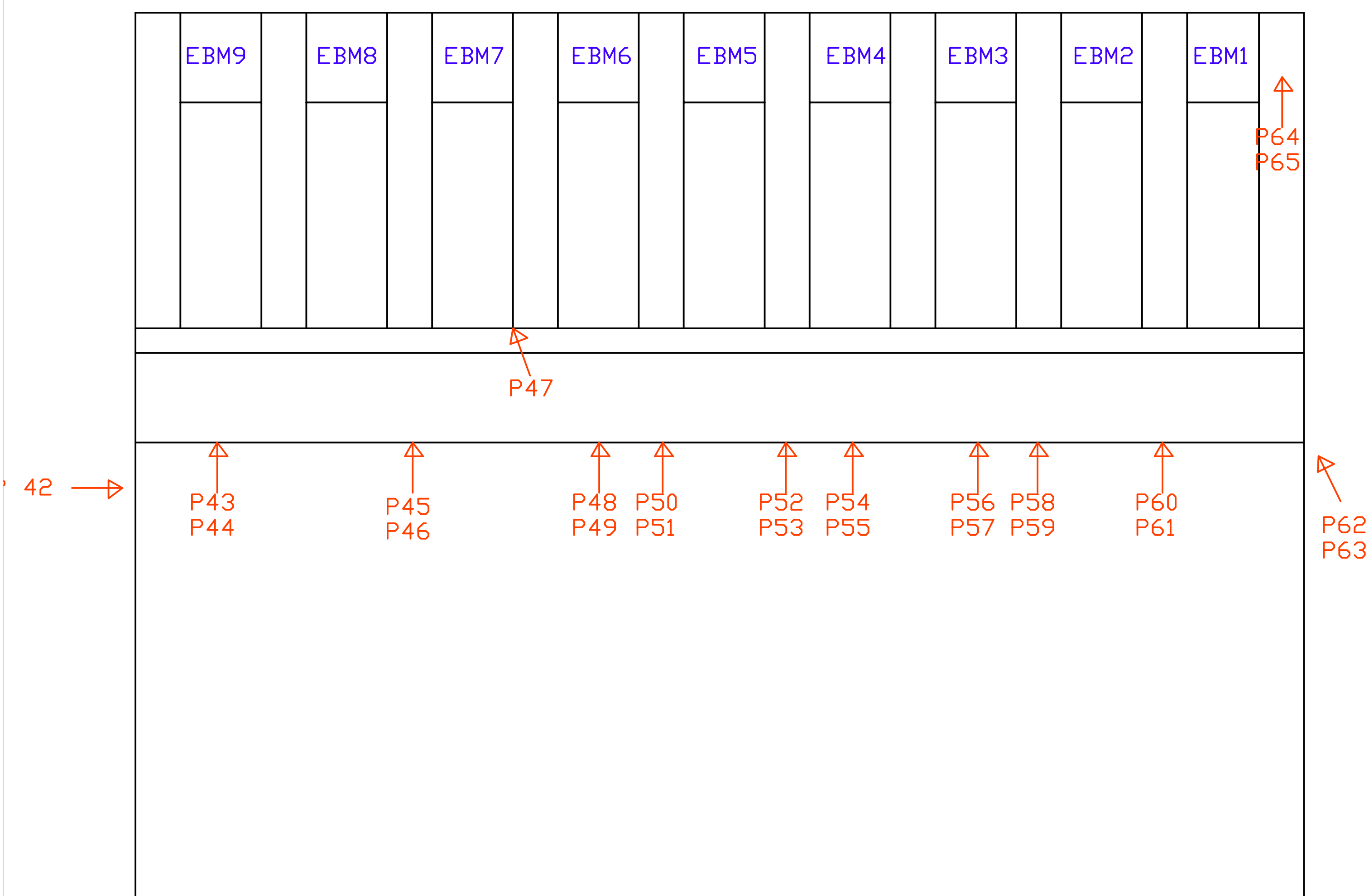
NORTH ABUTMENT



INSPECTOR:

DATE: 12/03/06

PAGE: 10/13

FIELD INSPECTION TEMPLATE
Bridge ID: S04-2 of 63174

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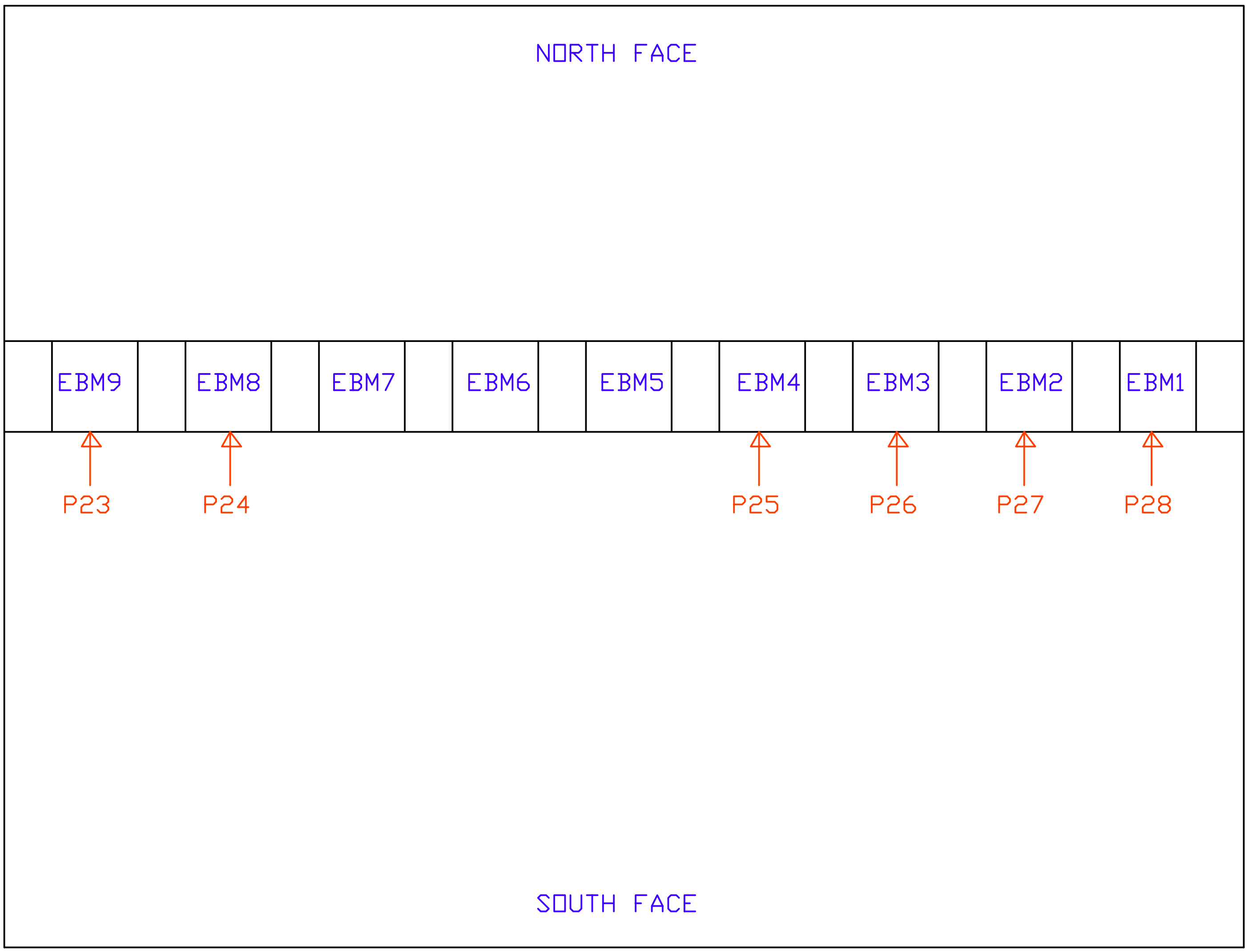
SOUTH PIER (PIER 1)



INSPECTOR:

DATE: 12/03/06

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FIELD INSPECTION TEMPLATE

Bridge ID: S04-2 of 63174

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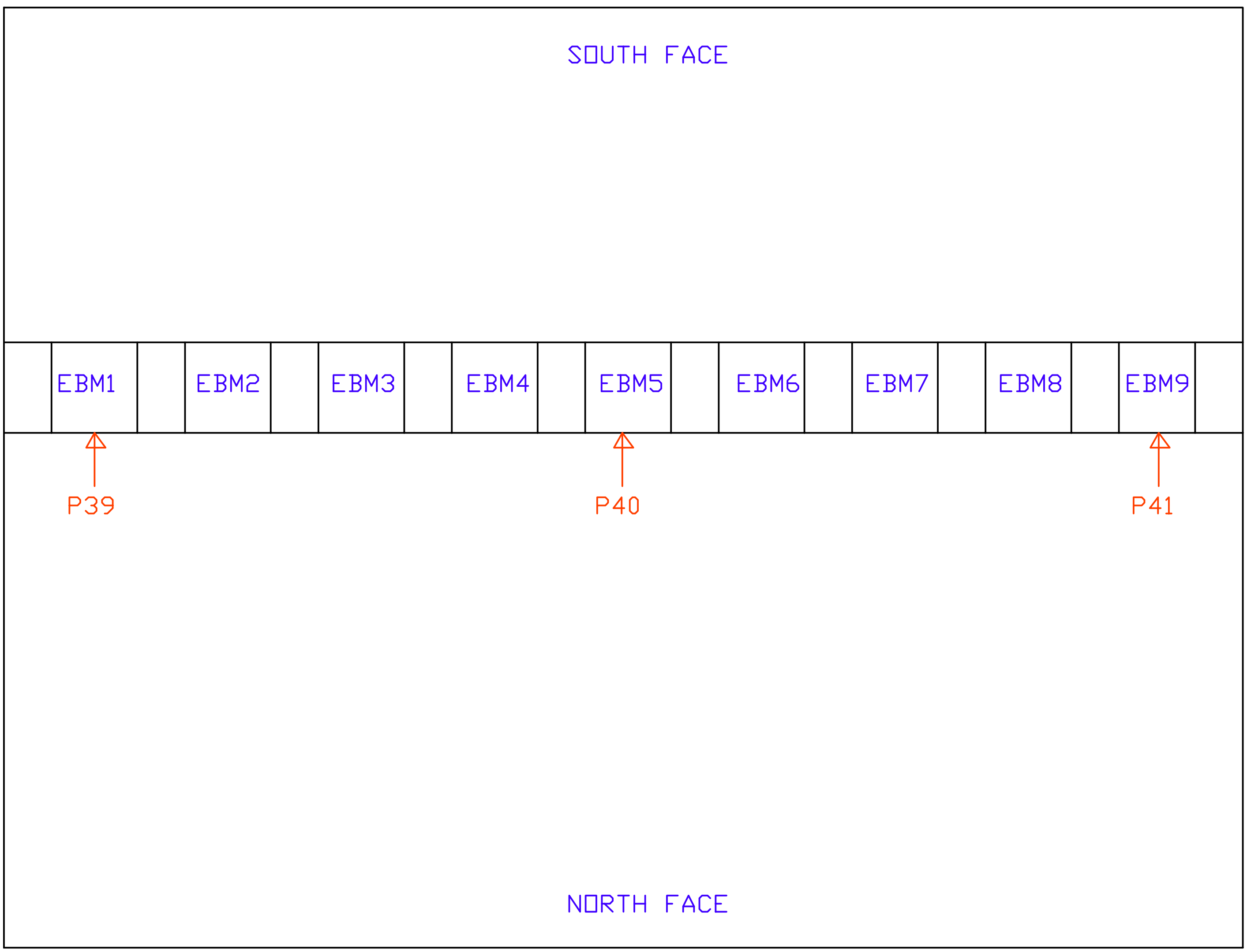
NORTH PIER (PIER 2)



INSPECTOR:

DATE: 12/03/06

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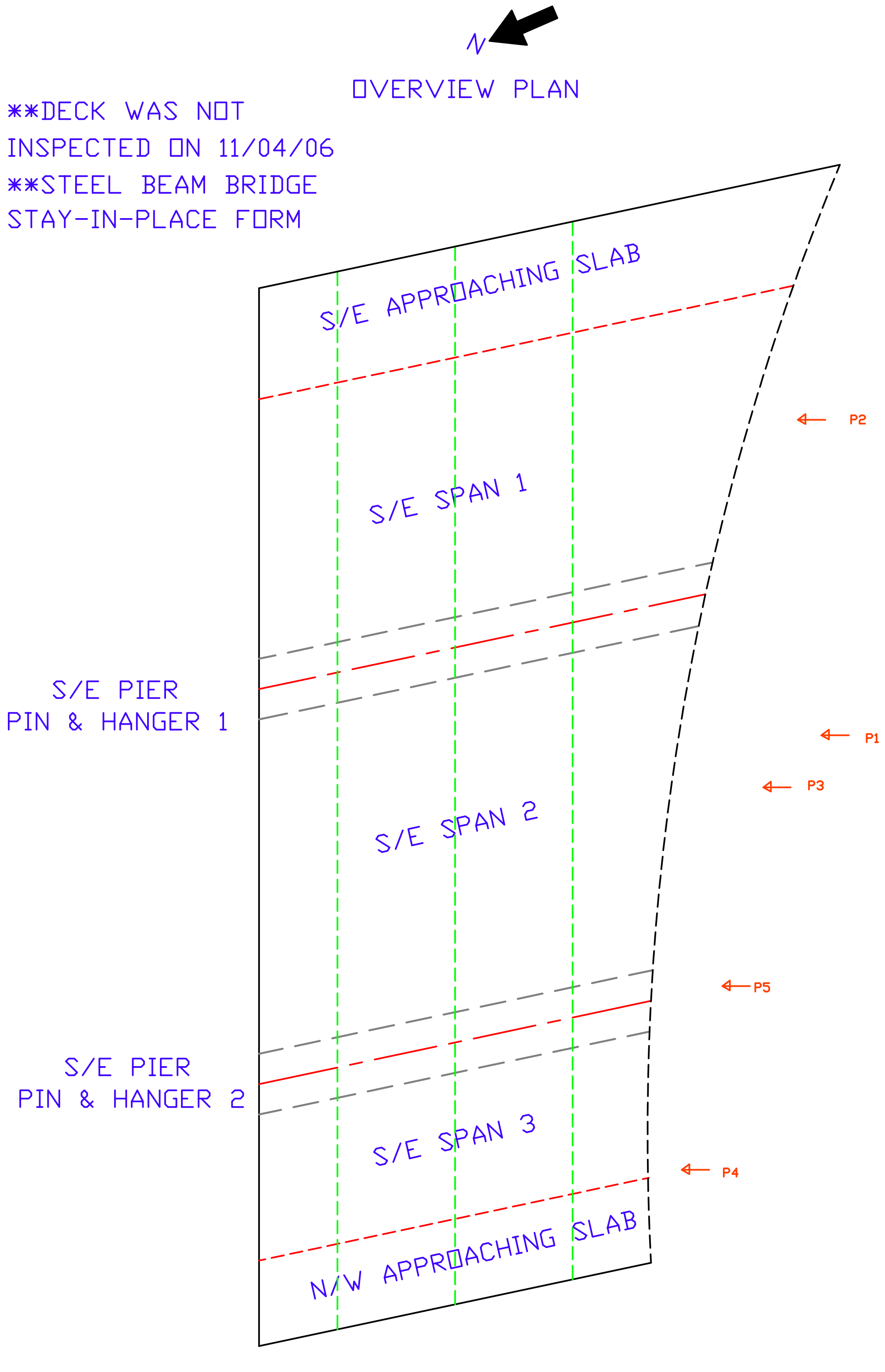
FIELD INSPECTION TEMPLATE

For S08 of 41027 EASTBOUND I-196 OVER MONROE AVE, KENT COUNTY GRAND REGION

OVERVIEW PLAN



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DATE: 11/04/06

PAGE: 1/ 13

FIELD INSPECTION TEMPLATE
Bridge ID: S08 of 41027

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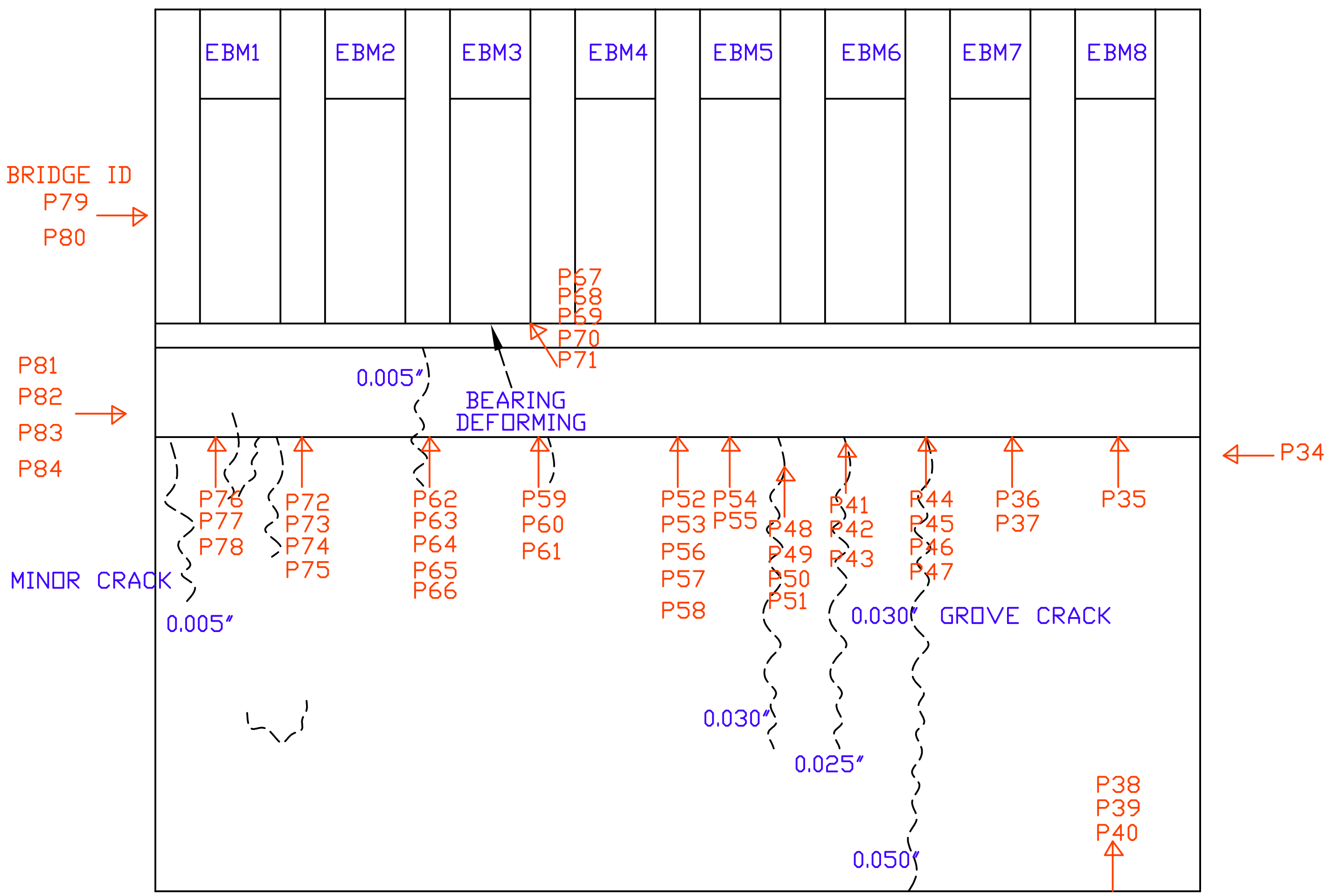
S/ E ABUTMENT



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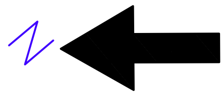
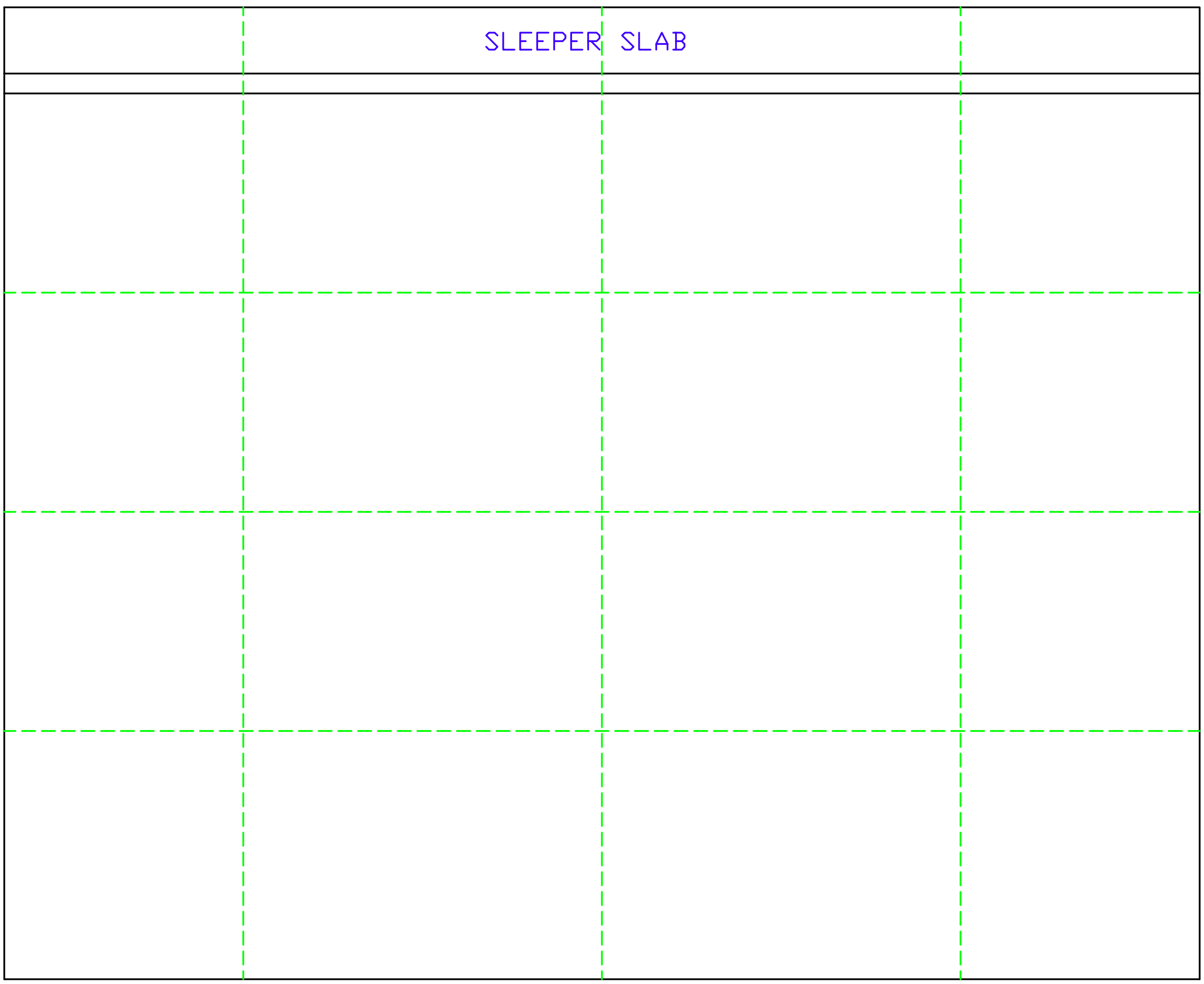
FIELD INSPECTION TEMPLATE

Bridge ID: S08 of 41027



S/E APPROACH SLAB



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DATE: 11/04/06

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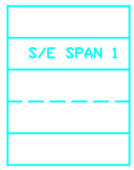
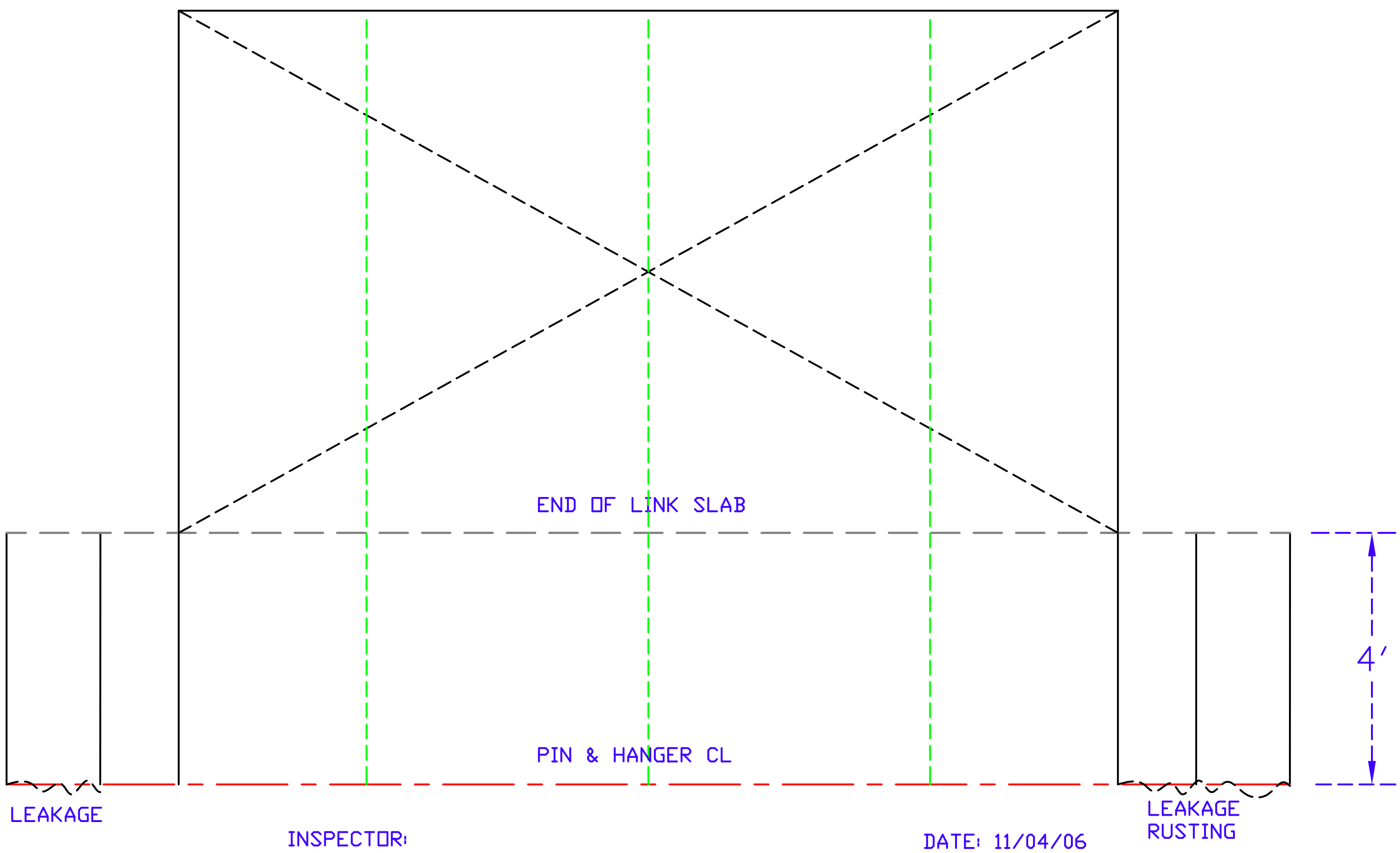
FIELD INSPECTION TEMPLATE

Bridge ID: S08 of 41027



BRIDGE DECK

S/E SPAN 1



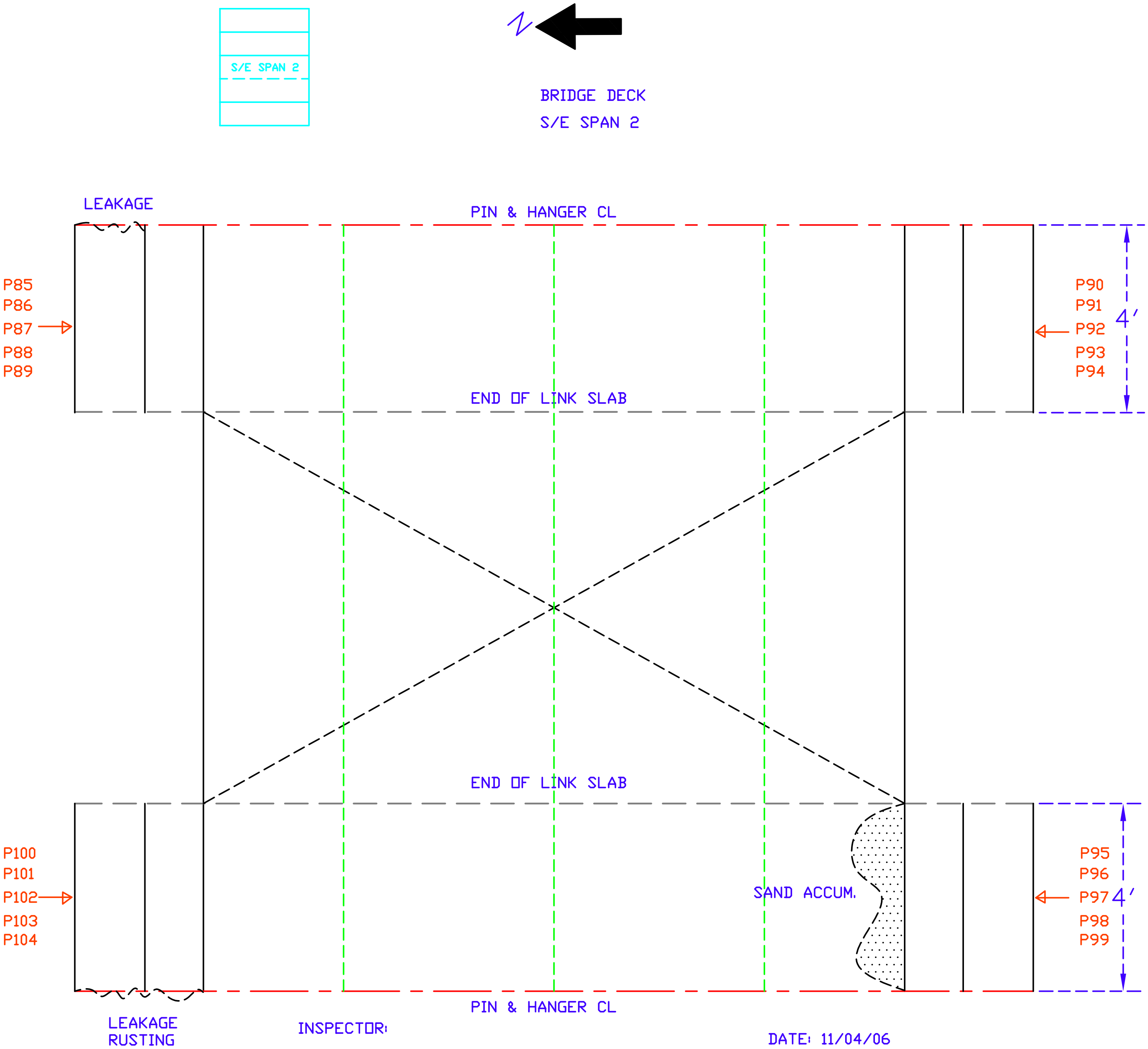
INSPECTOR:

DATE: 11/04/06

PAGE: 4/13

FIELD INSPECTION TEMPLATE

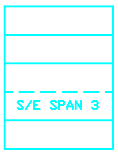
Bridge ID: S08 of 41027



INSPECTOR:

DATE: 11/04/06

PAGE: 5/13



FIELD INSPECTION TEMPLATE

Bridge ID: S08 of 41027

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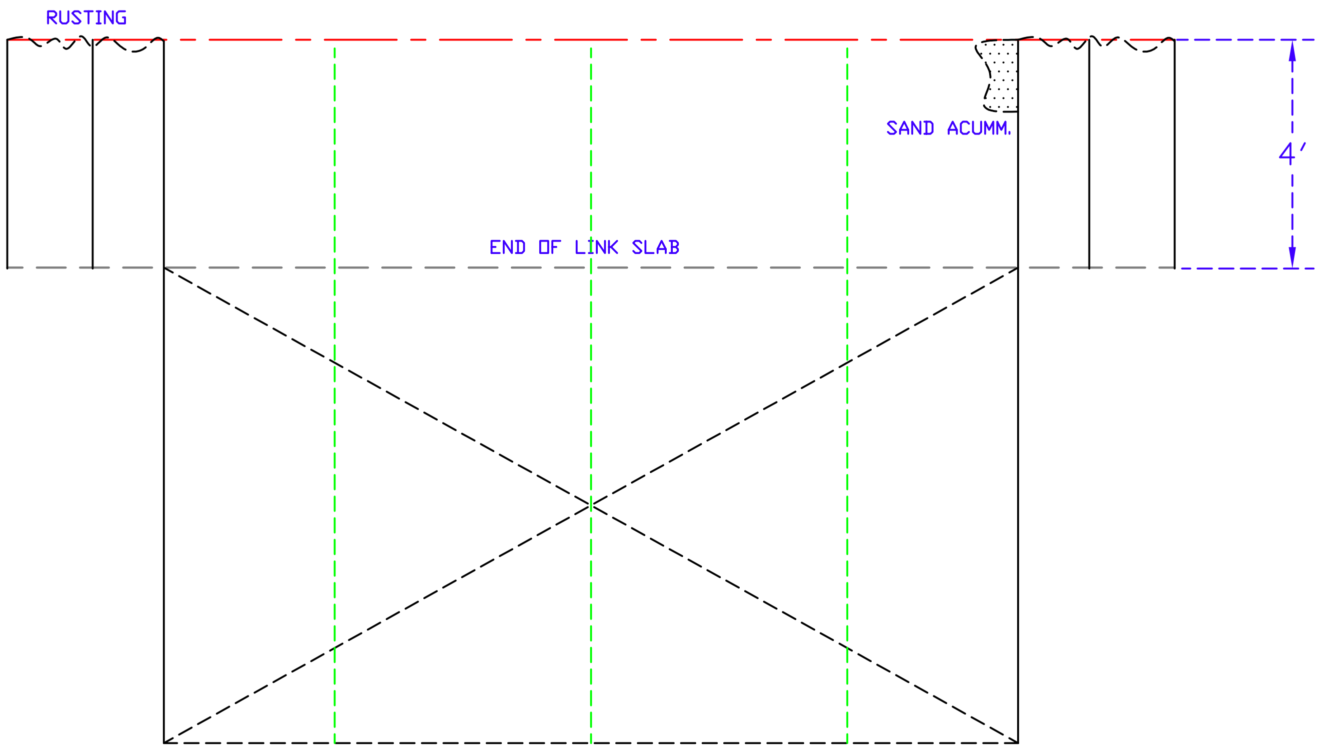
BRIDGE DECK

S/E SPAN 3



INSPECTOR:

DATE: 11/04/06

PAGE: 6/13

FIELD INSPECTION TEMPLATE

Bridge ID: S08 of 41027

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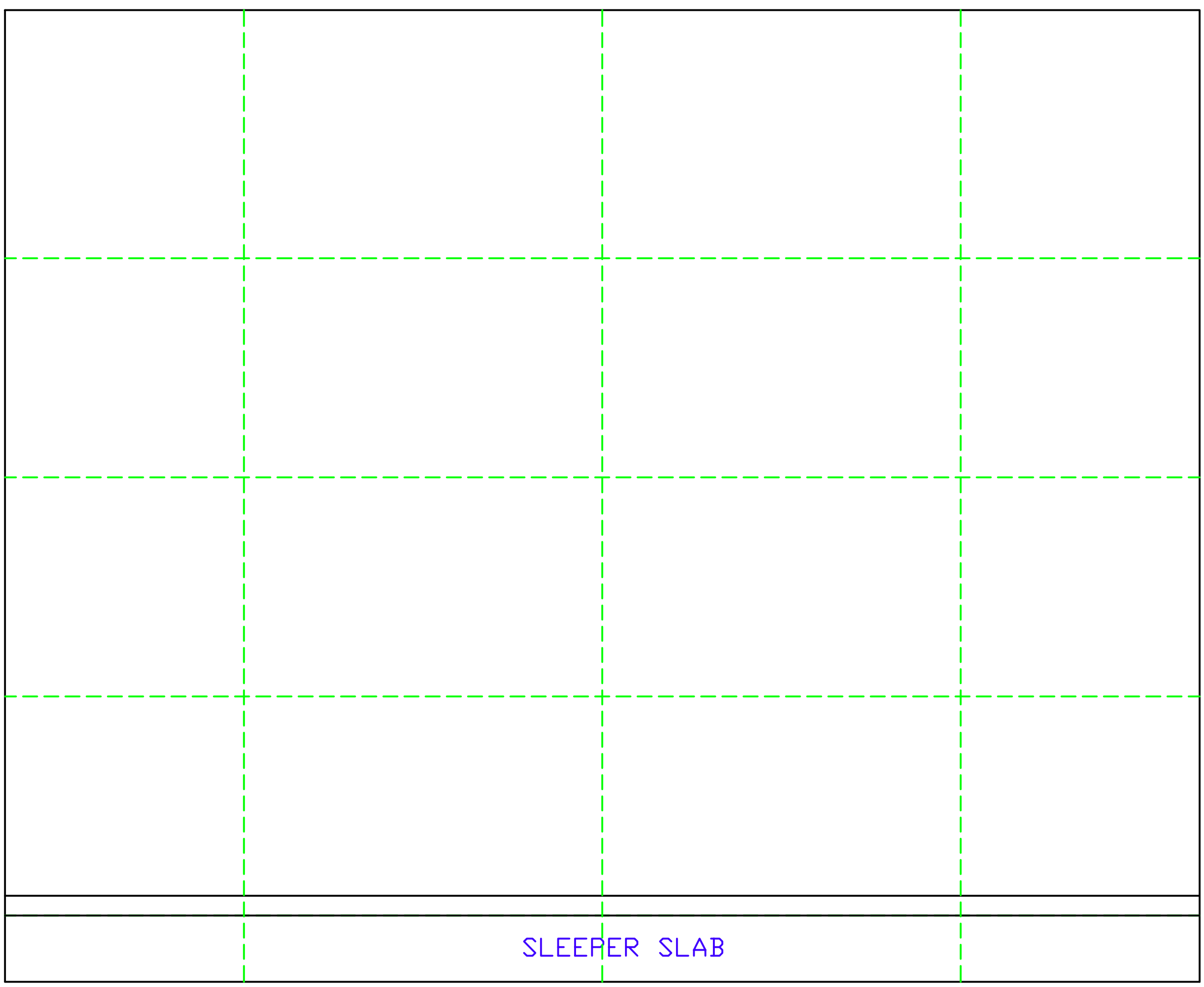

INSPECTOR:

DATE: 11/04/06

PAGE: 3/13

FIELD INSPECTION TEMPLATE
Bridge ID: S08 of 41027

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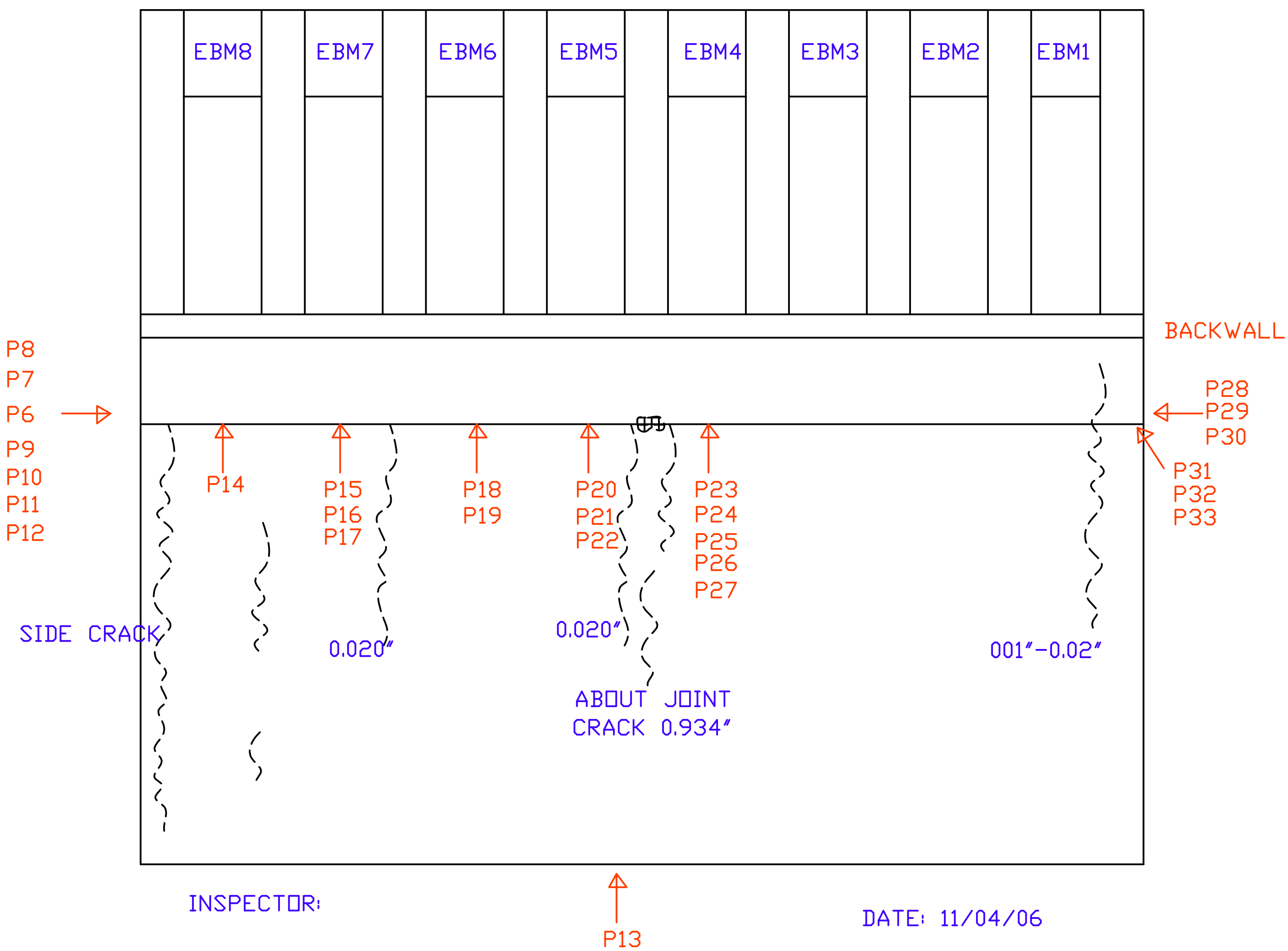
N/W ABUTMENT



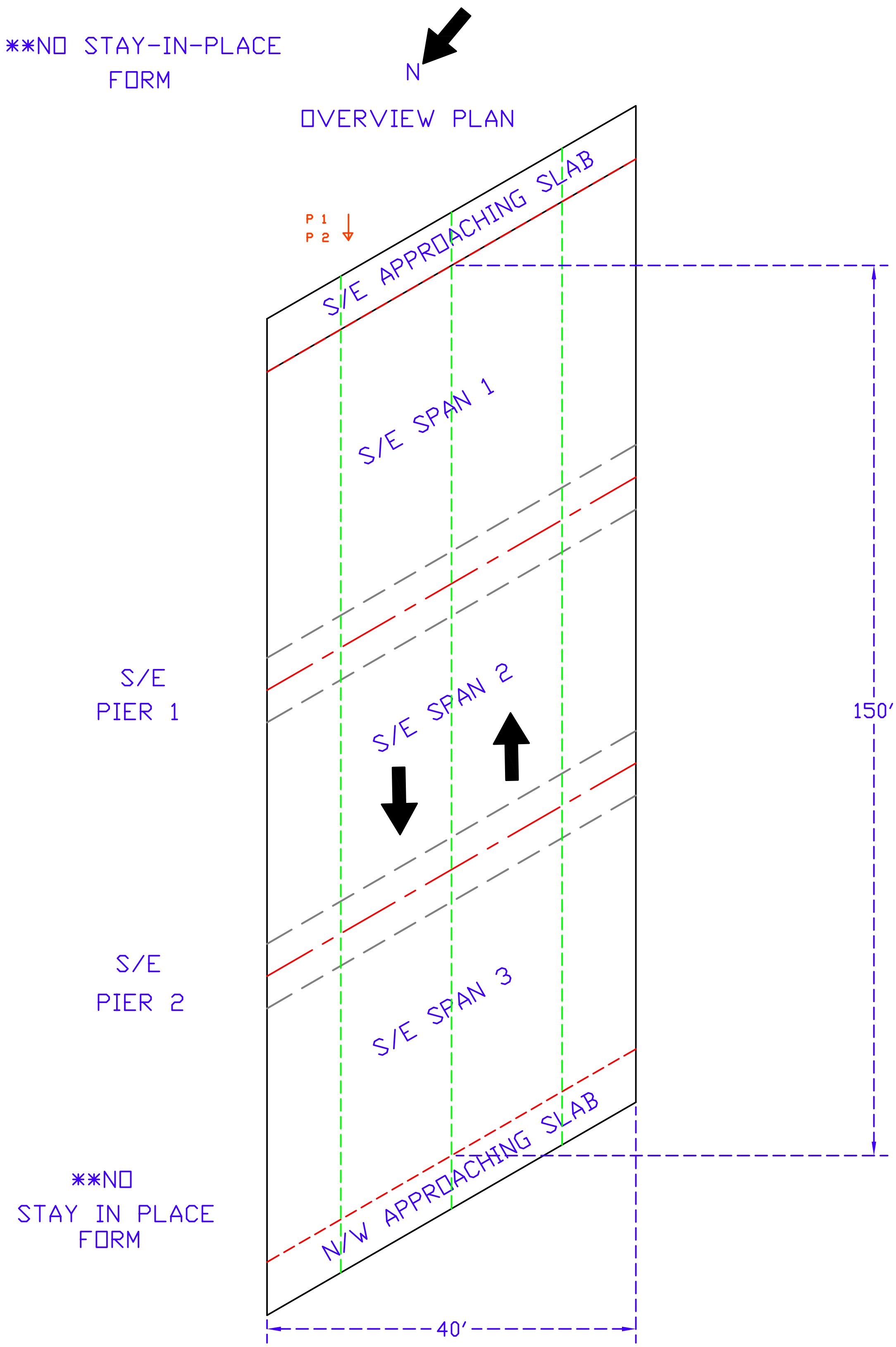
INSPECTOR:

DATE: 11/04/06

PAGE: 10/13

FIELD INSPECTION TEMPLATE

For B01 of 10042 ON M115 OVER BETZIE RIVER , BENZIE COUNTY, NORTH REGION



INSPECTOR:

DATE: 11/04/06

PAGE: 1/ 13

FIELD INSPECTION TEMPLATE
Bridge ID: B01 OF 10042

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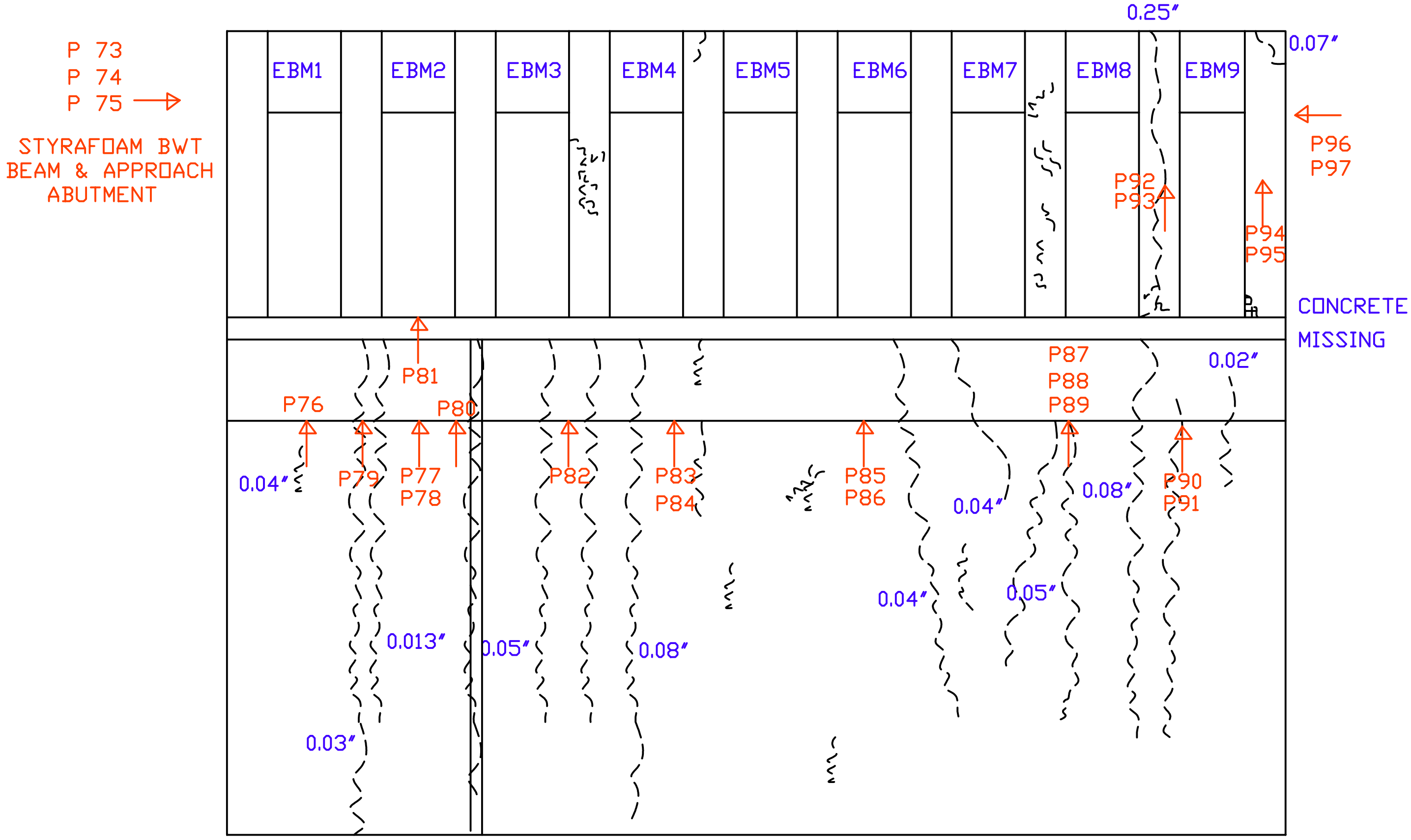
S/ E ABUTMENT



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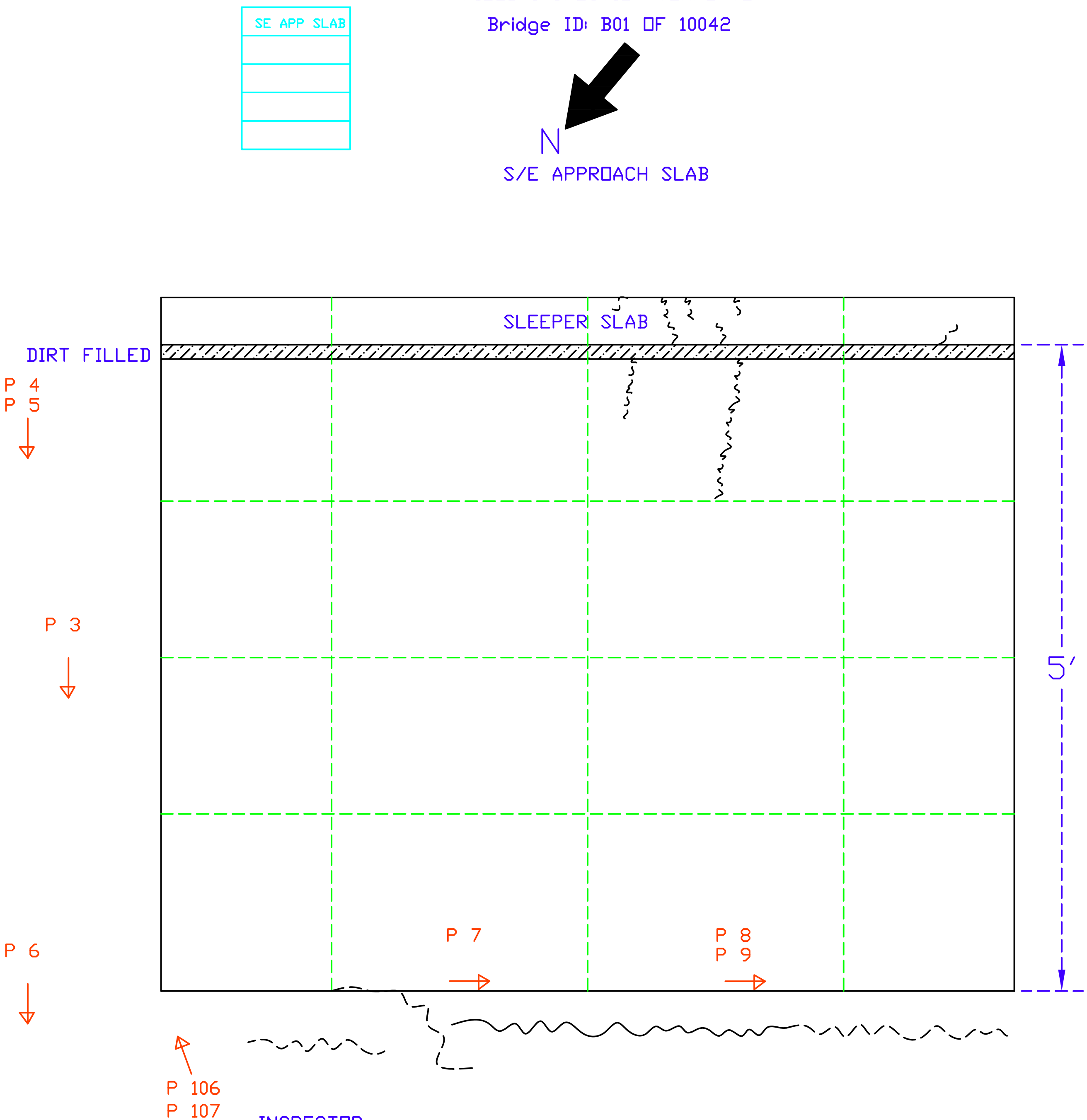
FIELD INSPECTION TEMPLATE

Bridge ID: B01 OF 10042



INSPECTOR:

DATE:

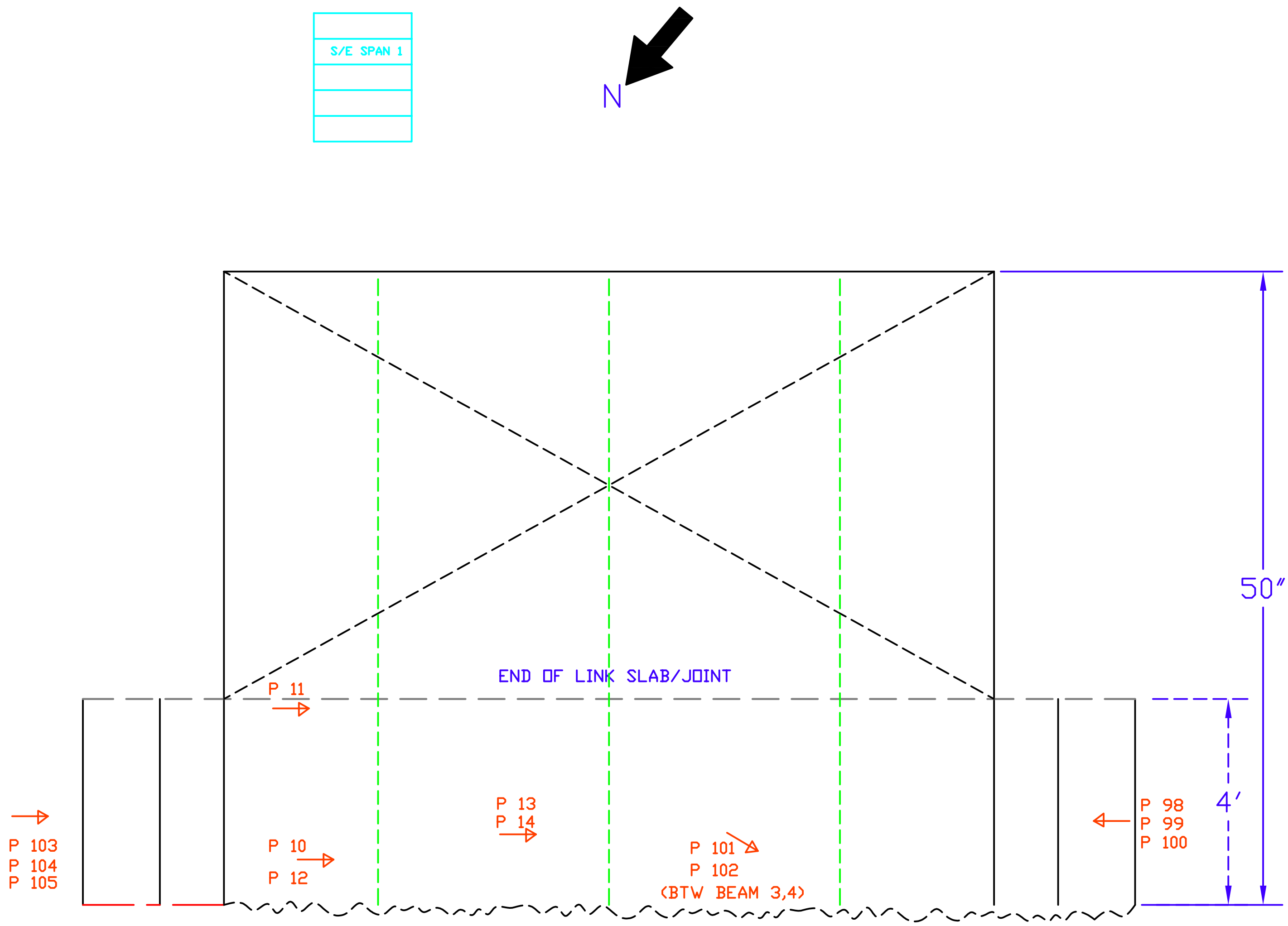
PAGE: 2/13

INSPECTOR:

FIELD INSPECTION TEMPLATE
Bridge ID: B01 OF 10042

BRIDGE DECK

S/E SPAN 1



INSPECTOR:

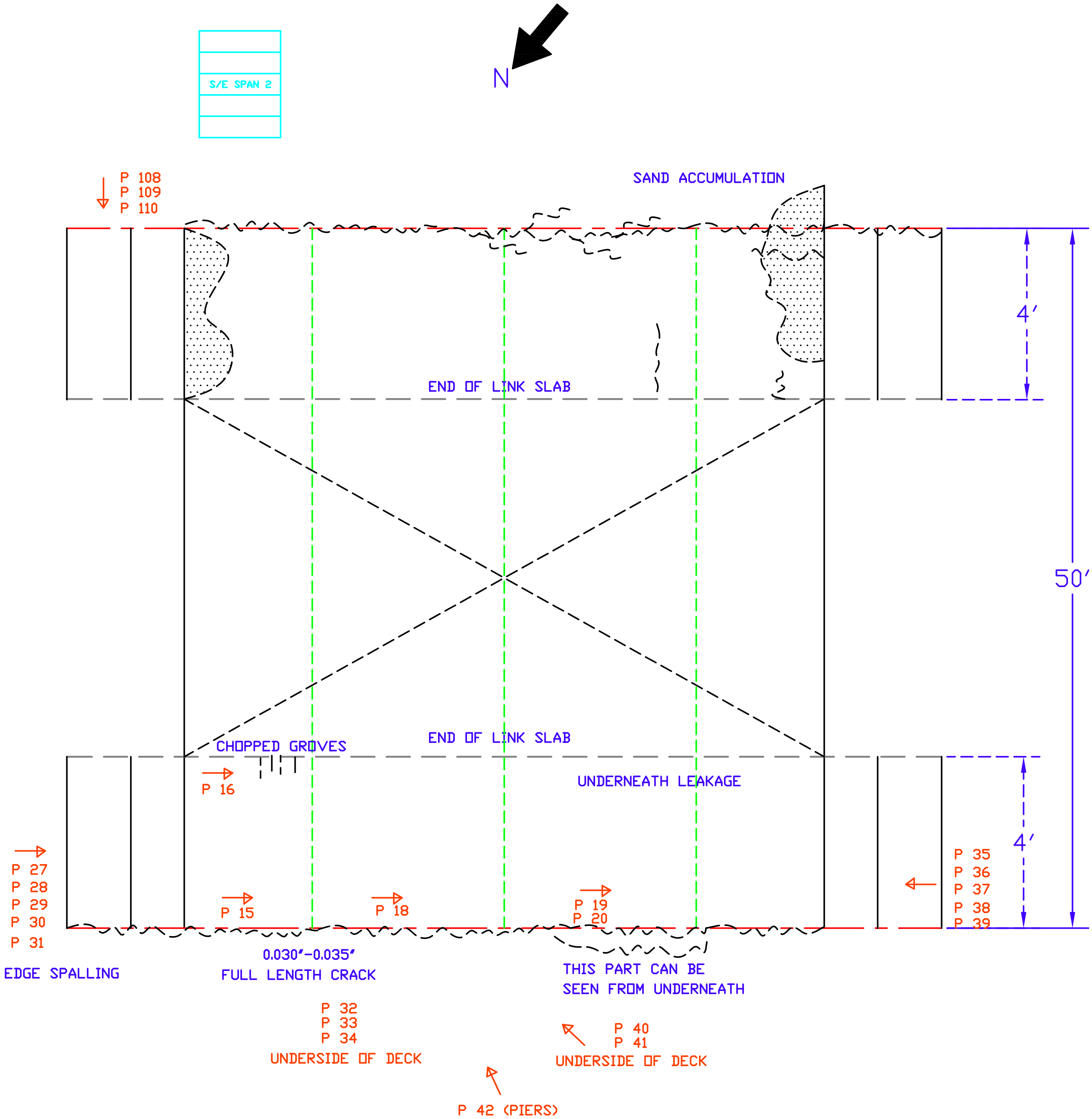
Note: Cracking
through
Middle of Link Slab
Not at Joint

DATE:

PAGE: 4/13

FIELD INSPECTION TEMPLATE
Bridge ID: B01 OF 10042

BRIDGE DECK
S/E SPAN 2



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DATE:

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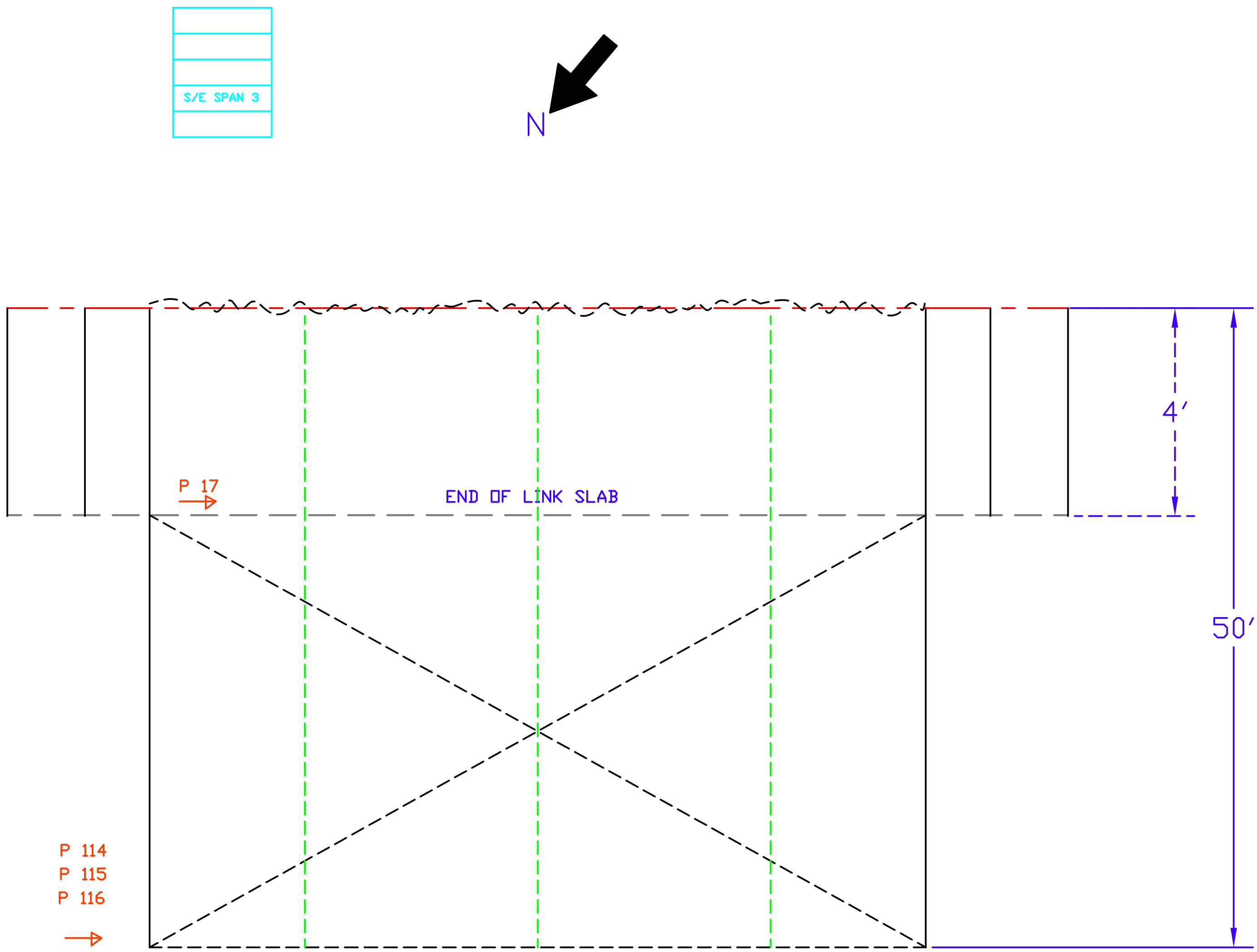
FIELD INSPECTION TEMPLATE
Bridge ID: B01 OF 10042

BRIDGE DECK

S/E SPAN 3



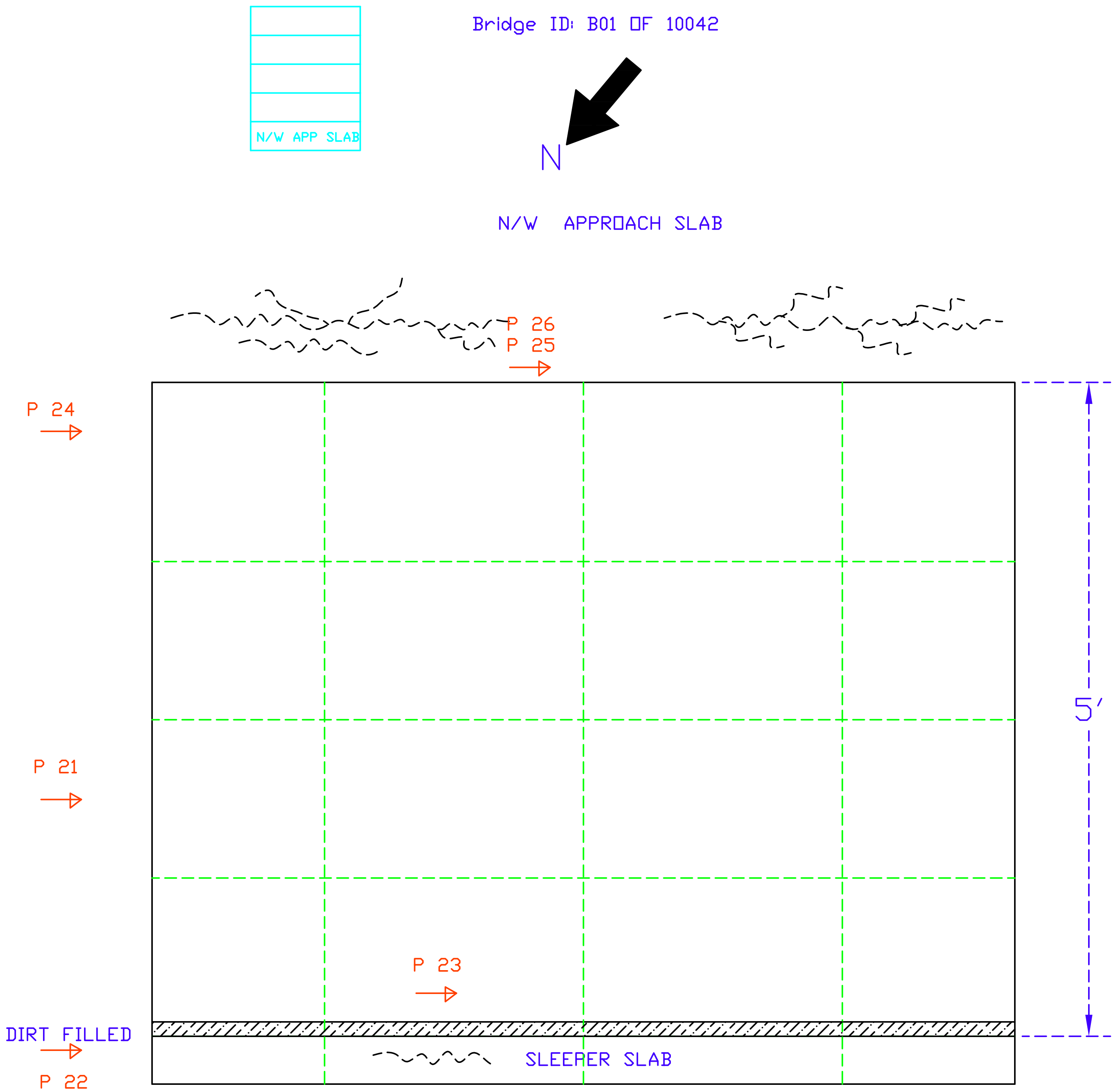
INSPECTOR:

DATE:

PAGE: 6/13

FIELD INSPECTION TEMPLATE

Bridge ID: B01 OF 10042



INSPECTOR:

DATE:

PAGE: 3/13

FIELD INSPECTION TEMPLATE
Bridge ID: B01 OF 10042

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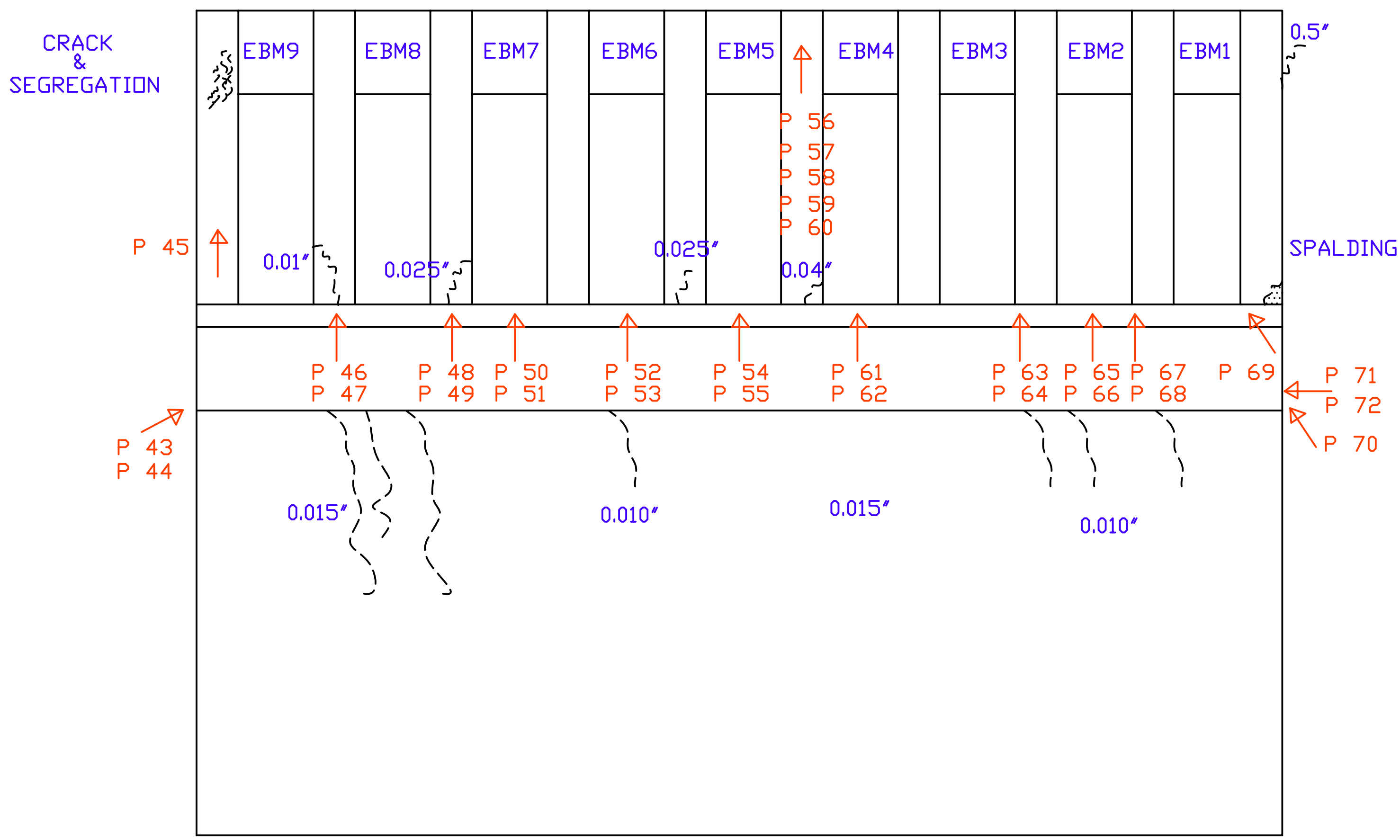


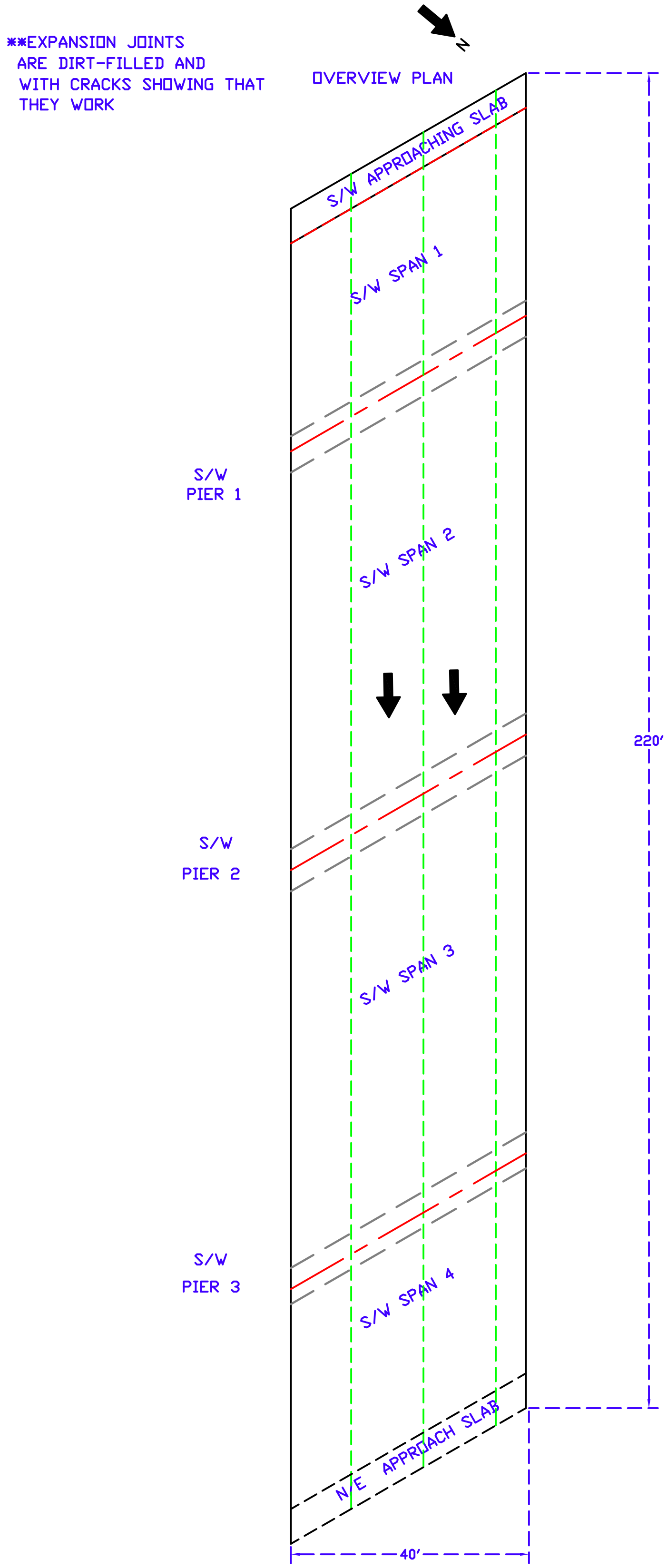
INSPECTOR:

DATE:

PAGE: 10/13

FIELD INSPECTION TEMPLATE

For S12-3 OF 25042 ON I-69 EB OVER I-75, GENESEE COUNTY, BAY REGION



INSPECTOR:

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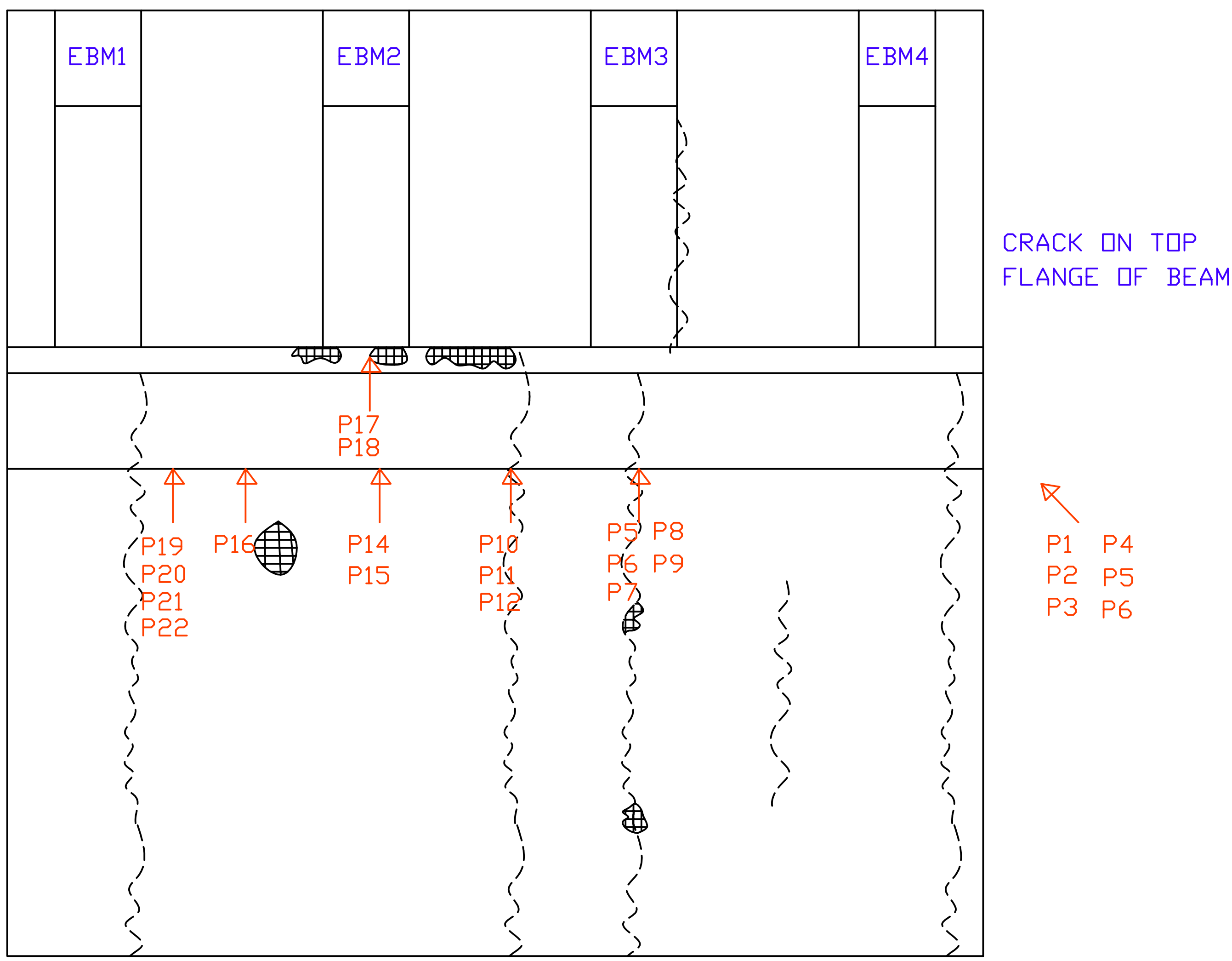
FIELD INSPECTION TEMPLATE
Bridge ID: S12-3 of 25042

**north is out of the page.

S/ W ABUTMENT



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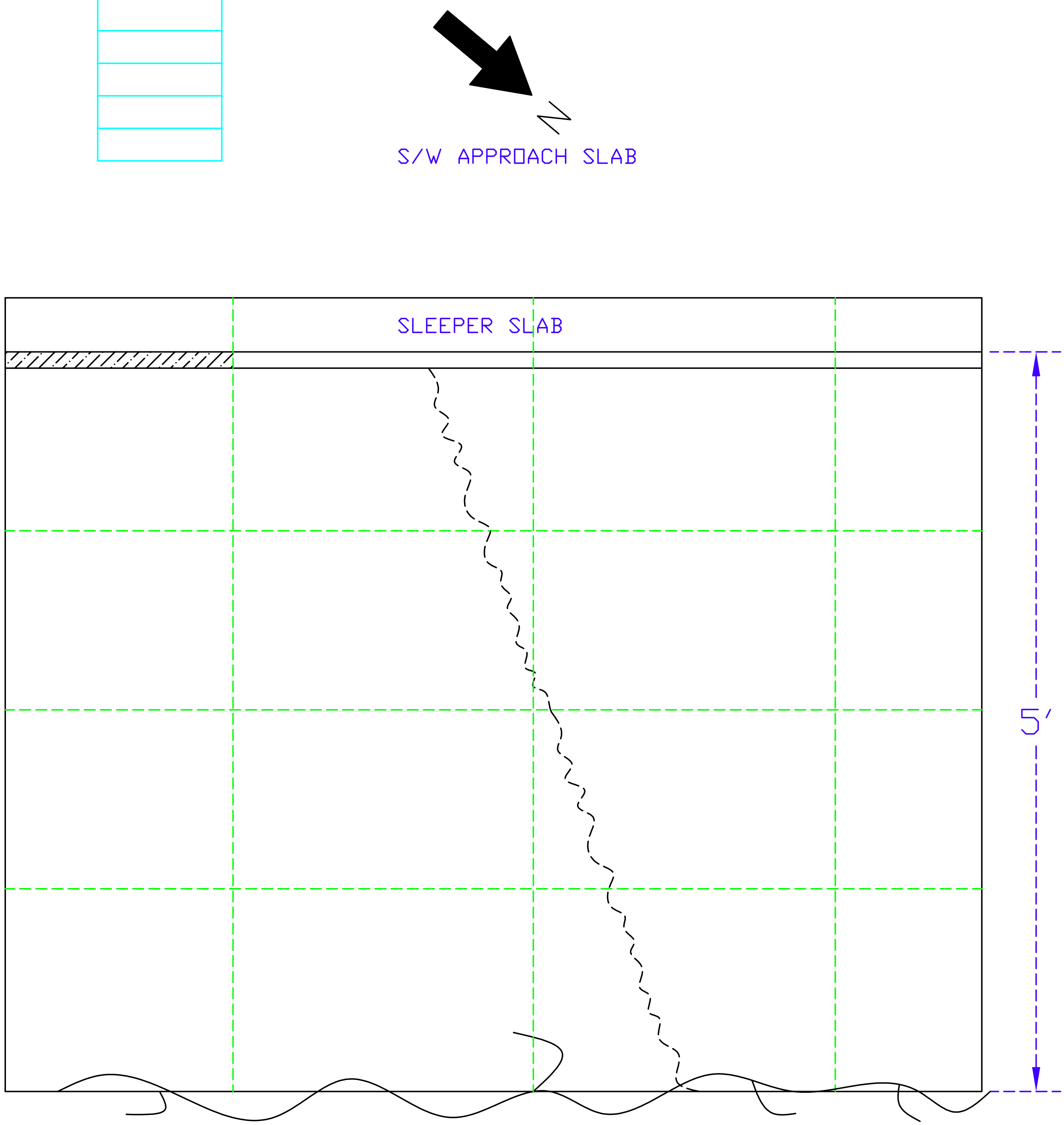
FIELD INSPECTION TEMPLATE

Bridge ID: S12-3 of 25042

SW APP SLAB

S/W APPROACH SLAB



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P 80
P 81
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DATE:

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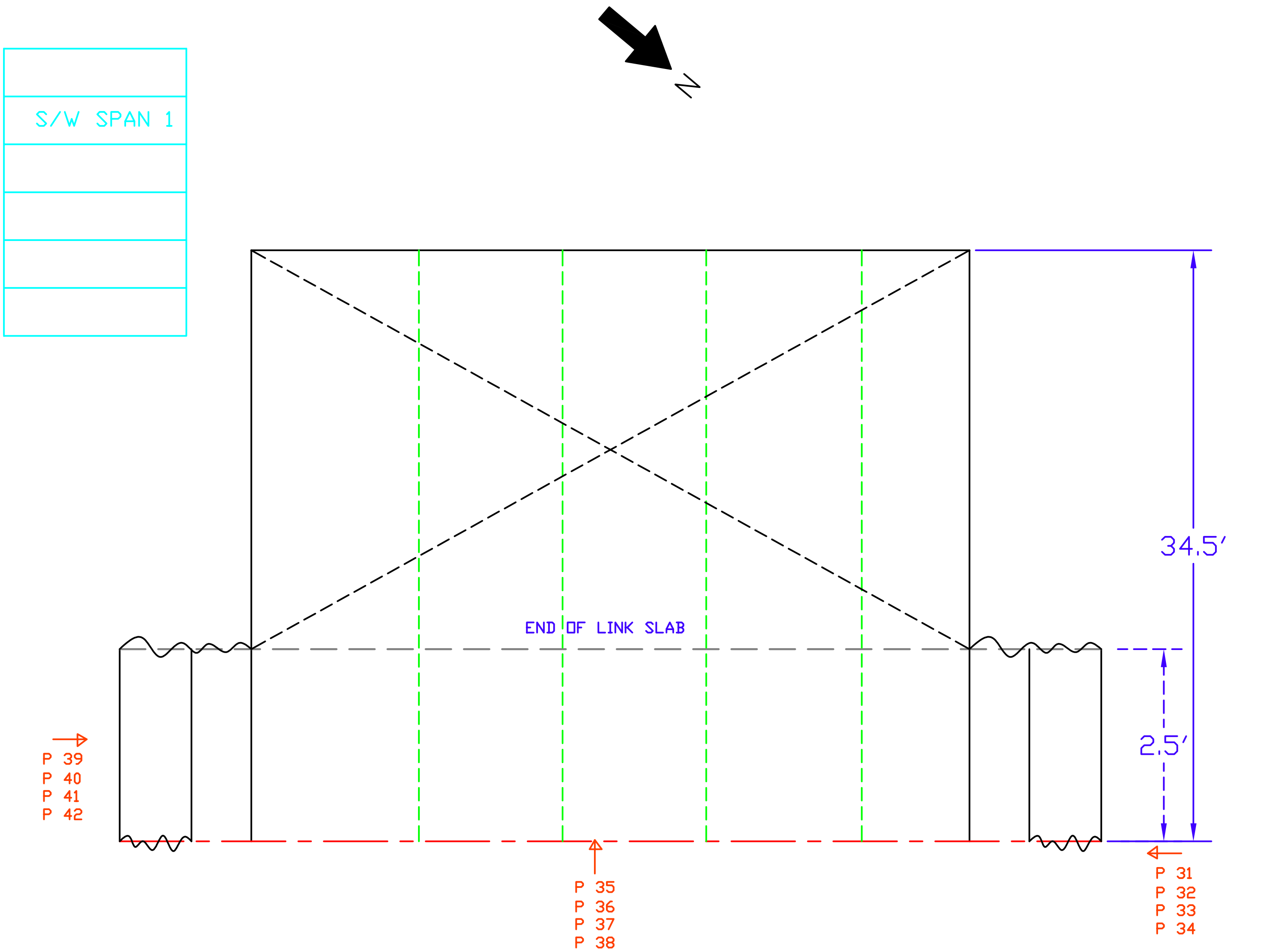
FIELD INSPECTION TEMPLATE
Bridge ID: S12-3 of 25042

BRIDGE DECK

S/W SPAN 1



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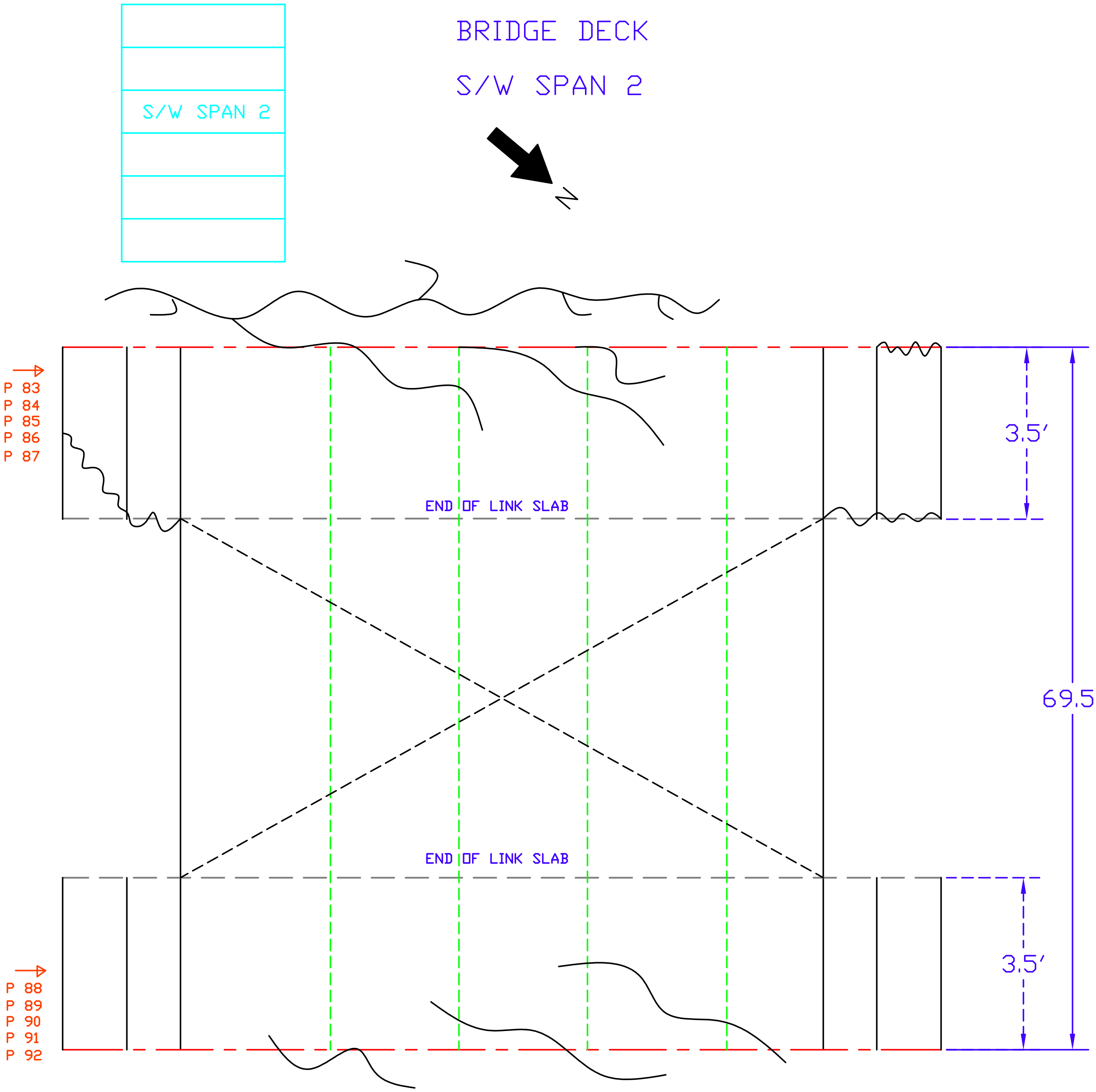
FIELD INSPECTION TEMPLATE
Bridge ID: S12-3 of 25042

BRIDGE DECK

S/W SPAN 2



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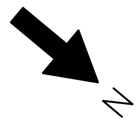
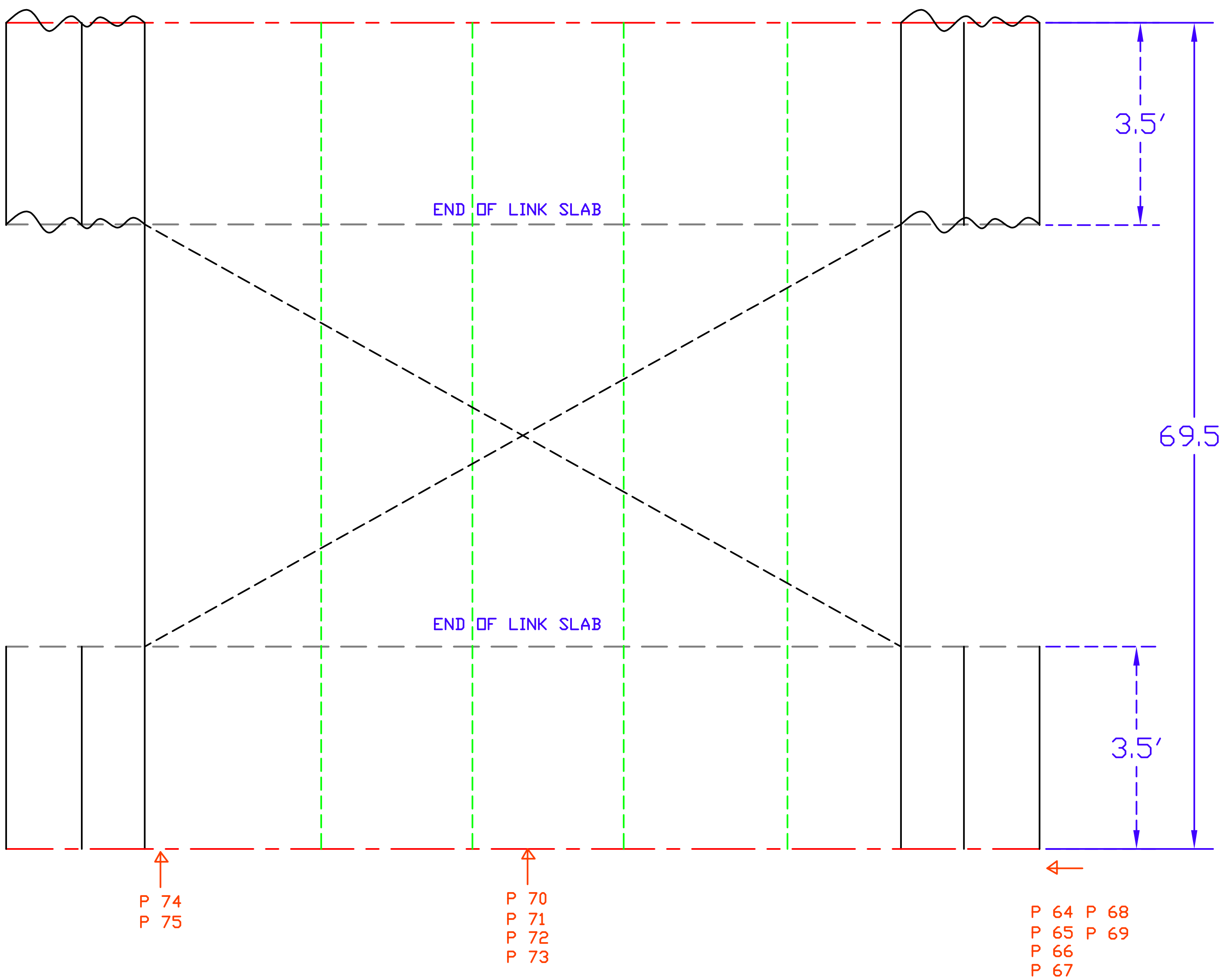
FIELD INSPECTION TEMPLATE
Bridge ID: S12-3 of 25042

BRIDGE DECK

S/W SPAN 3

S/W SPAN 3





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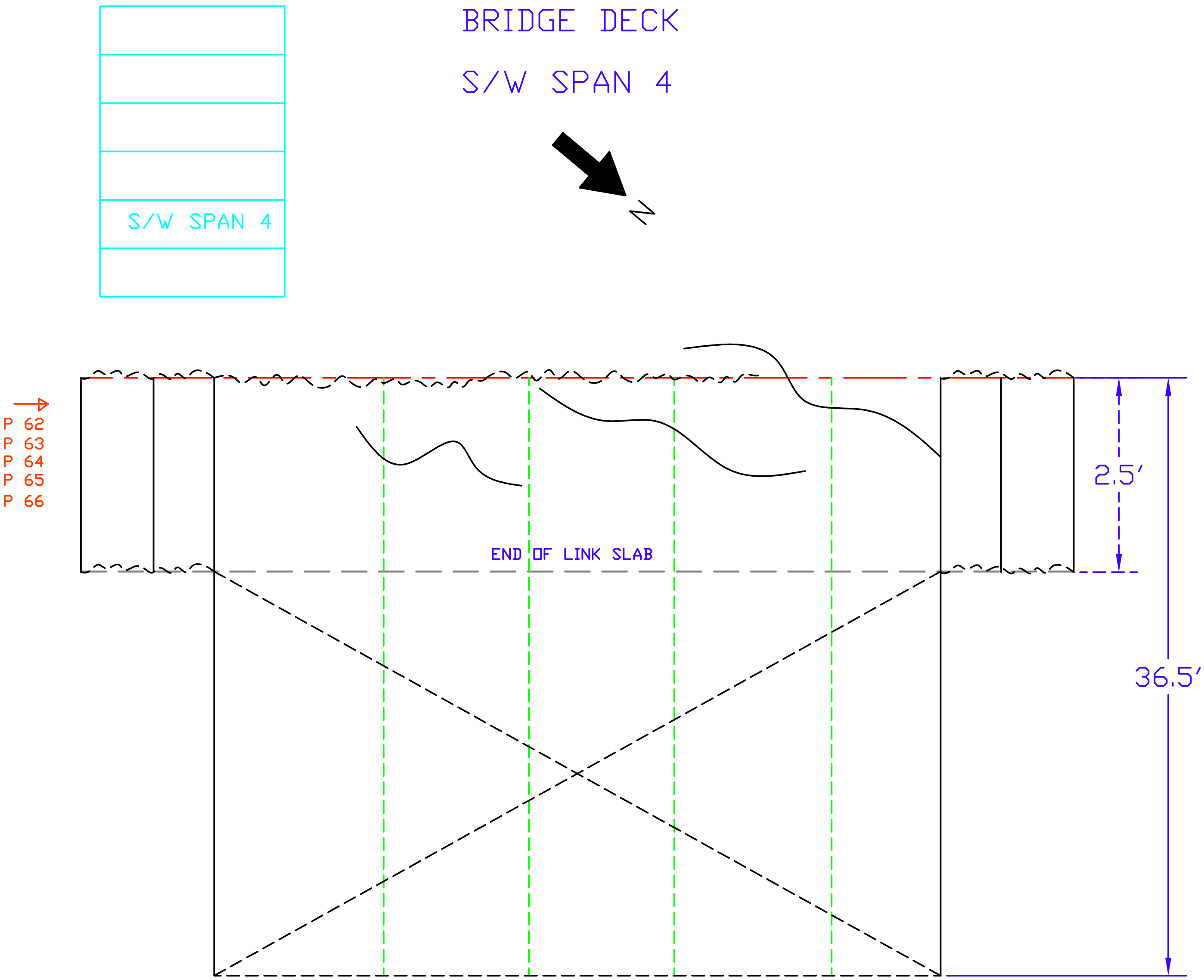
FIELD INSPECTION TEMPLATE
Bridge ID: S12-3 of 25042

BRIDGE DECK

S/W SPAN 4



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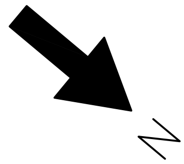
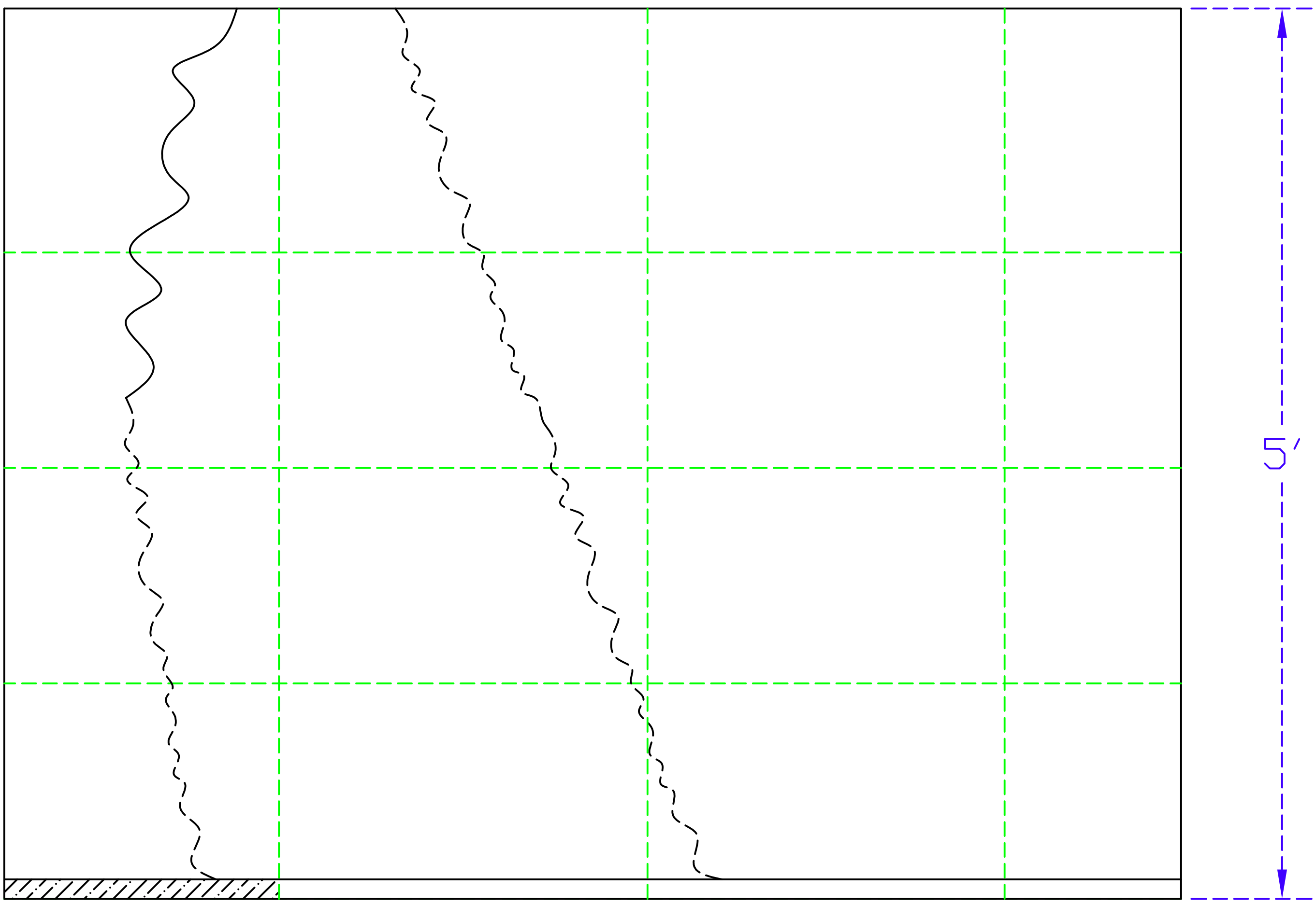
FIELD INSPECTION TEMPLATE

Bridge ID: S12-3 of 25042

N/E APP SLAB



N/E APPROACH SLAB



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P 104
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FIELD INSPECTION TEMPLATE
Bridge ID: S12-3 of 25042

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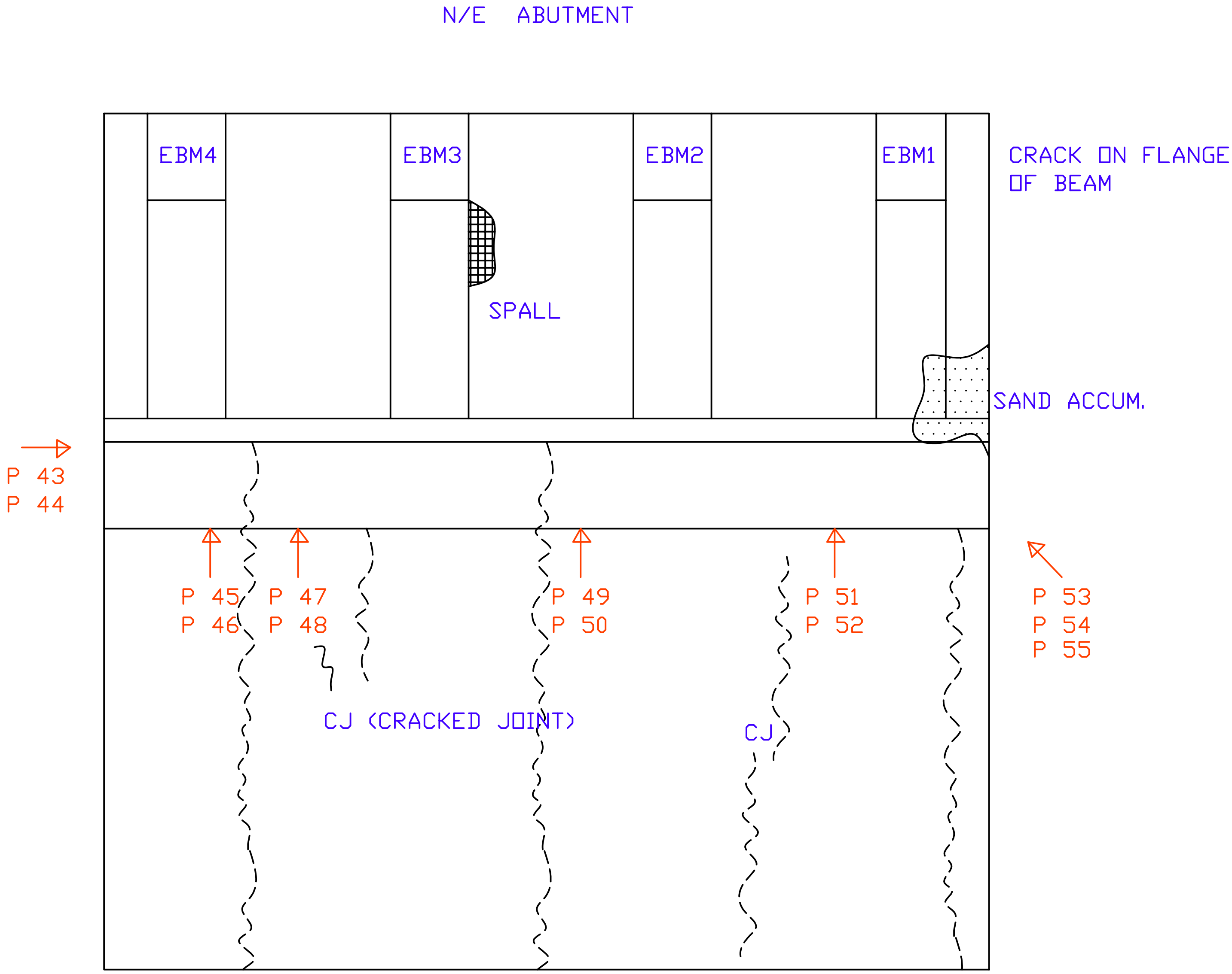

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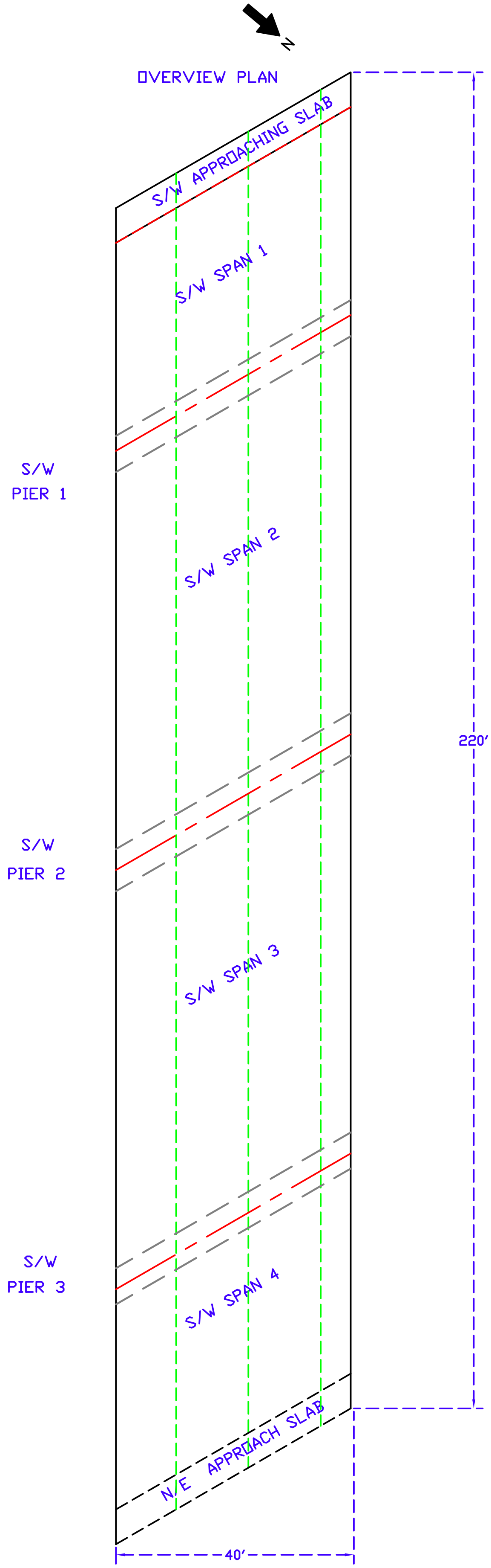
FIELD INSPECTION TEMPLATE

For S12-4 OF 25042 ON I-69 WB OVER I-75 , GENESEE COUNTY, BAY REGION



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FIELD INSPECTION TEMPLATE

Bridge ID: S12-4 of 25042

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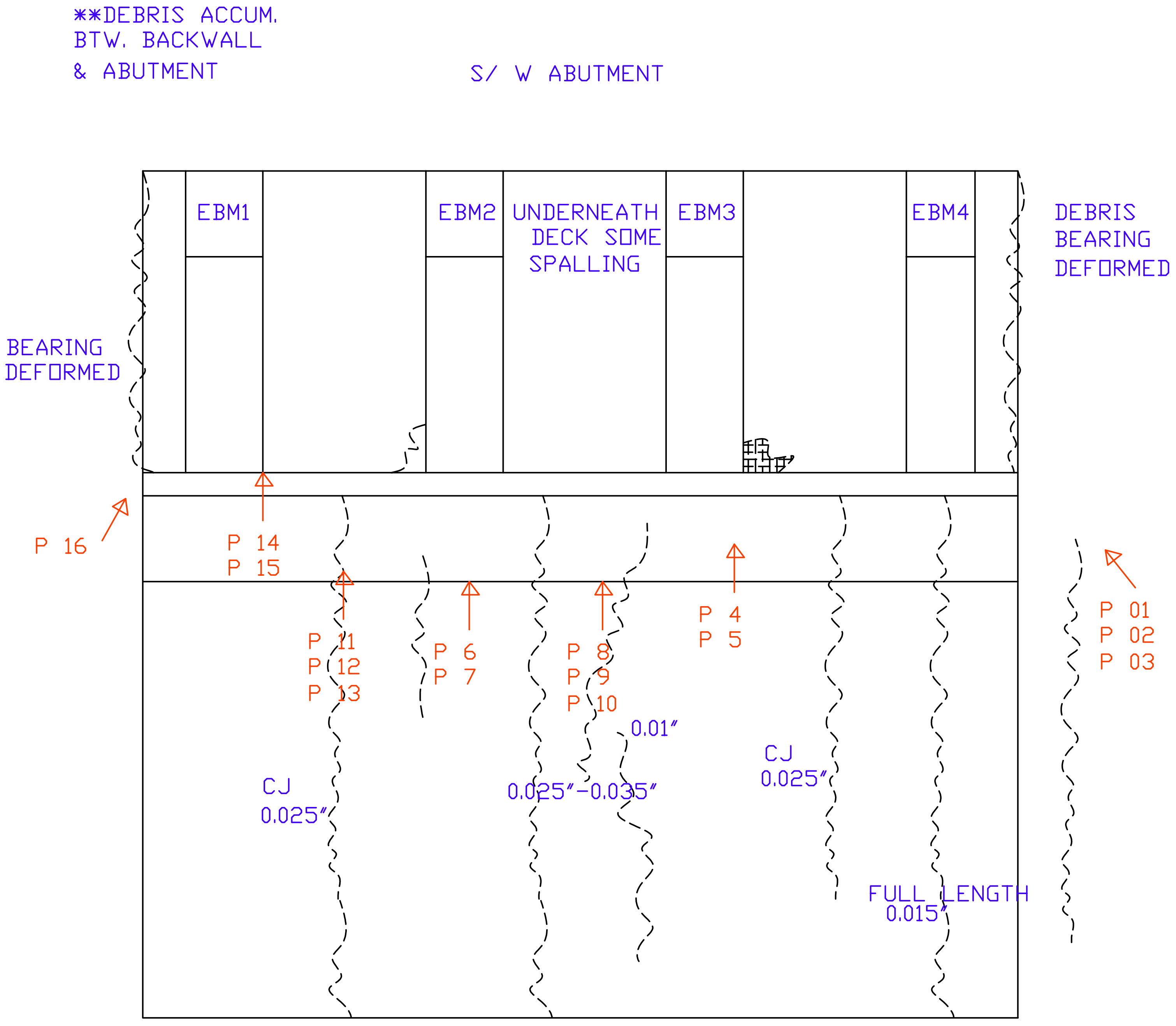

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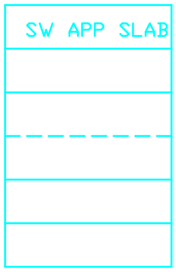
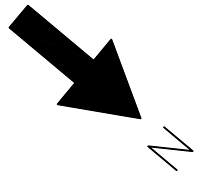


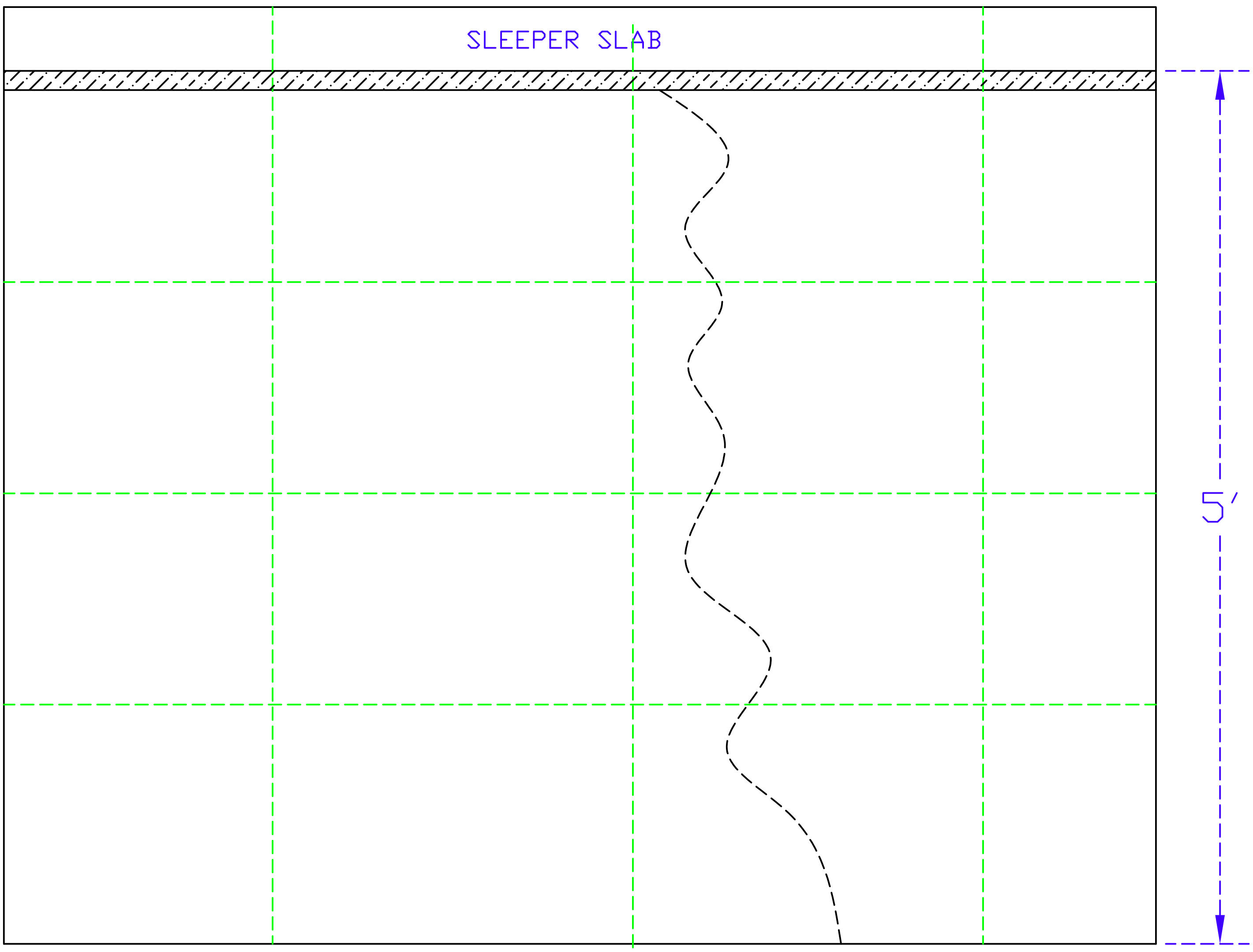
FIELD INSPECTION TEMPLATE

Bridge ID: S12-4 of 25042



S/W APPROACH SLAB

**JOINT BETWEEN SLEEPER SLAB & PAVEMENT NOT VISIBLE



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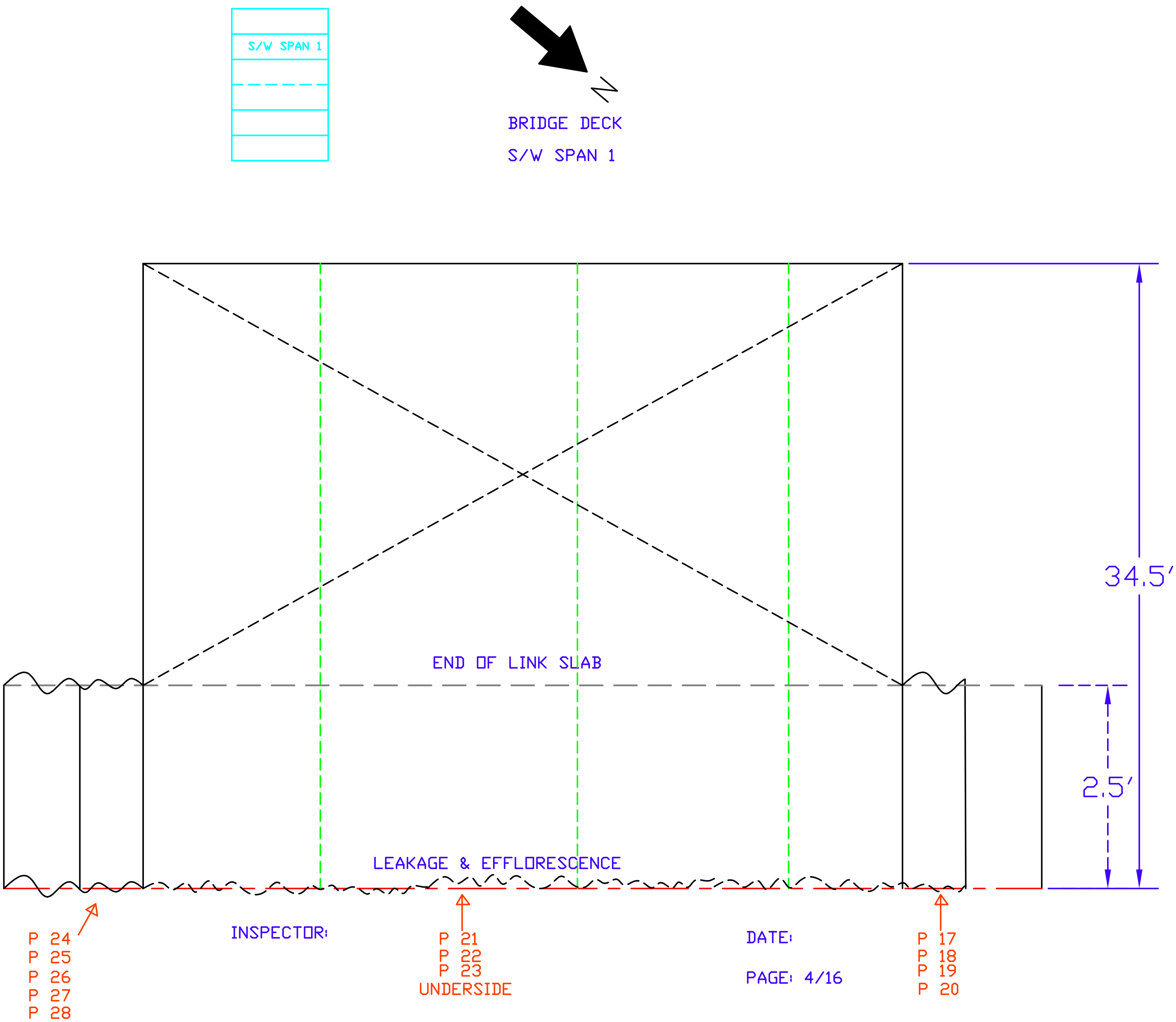
FIELD INSPECTION TEMPLATE
Bridge ID: S12-4 of 25042



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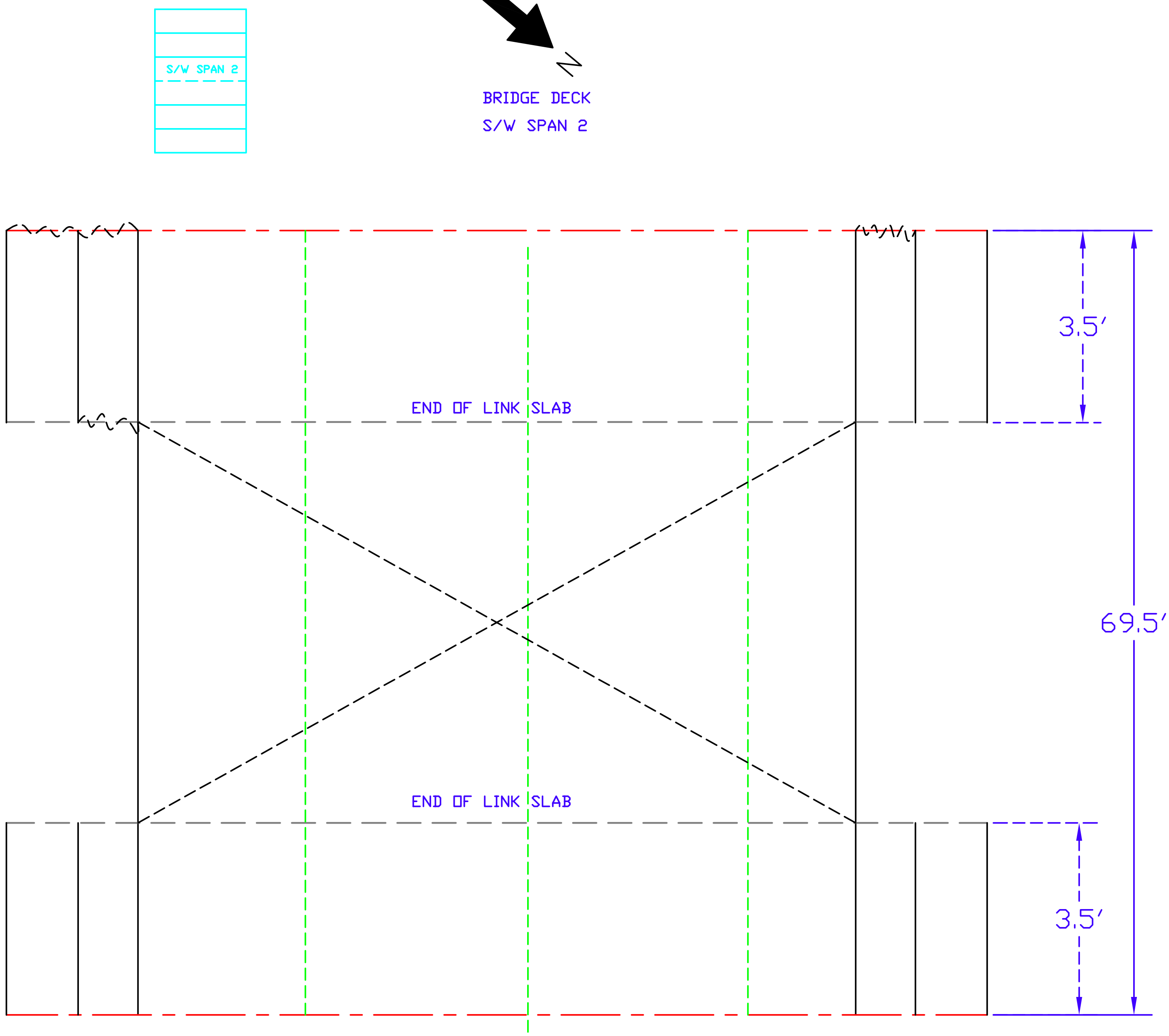
FIELD INSPECTION TEMPLATE
Bridge ID: S12-4 of 25042



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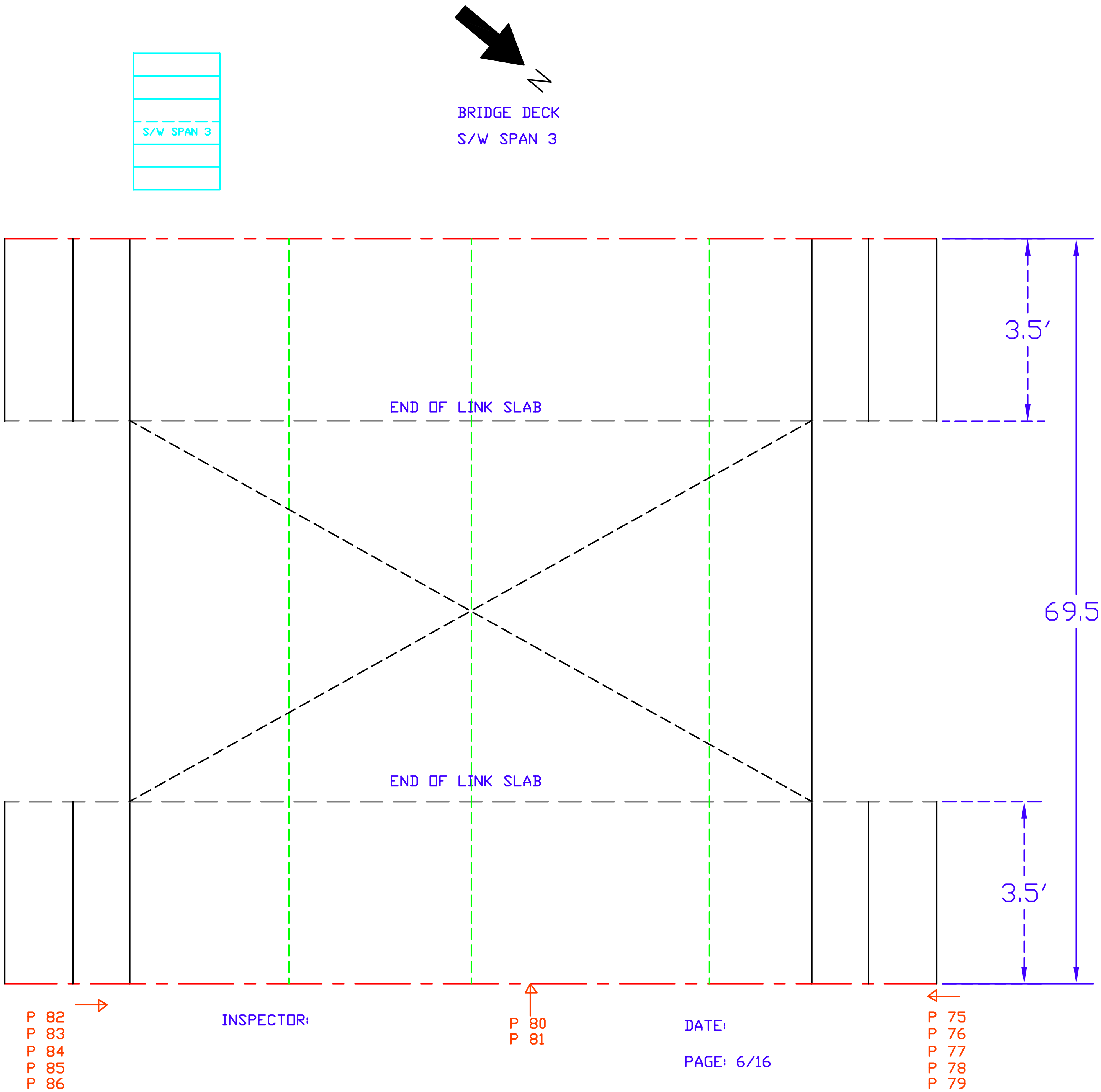
FIELD INSPECTION TEMPLATE
Bridge ID: S12-4 of 25042



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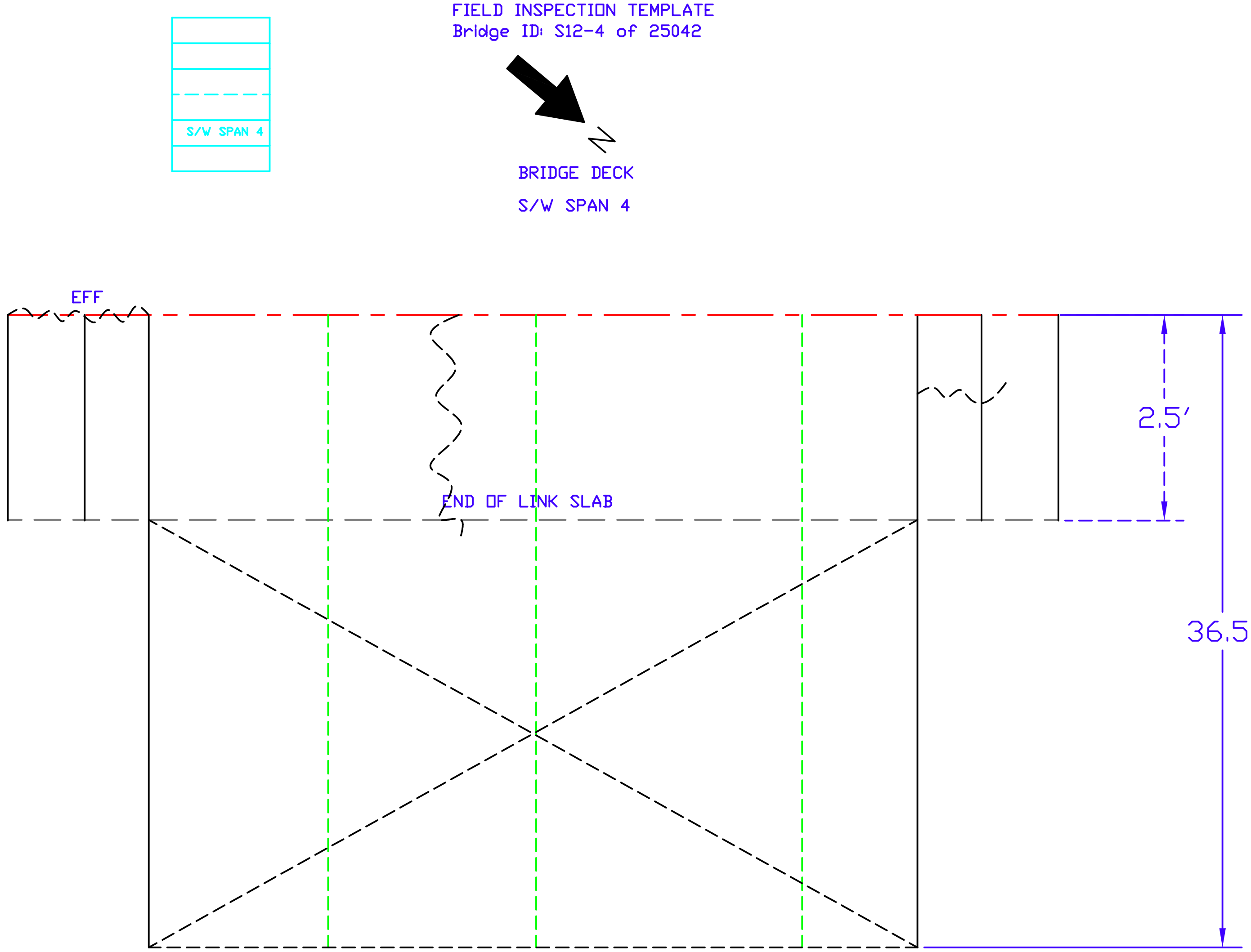
FIELD INSPECTION TEMPLATE
Bridge ID: S12-4 of 25042

BRIDGE DECK

S/W SPAN 4



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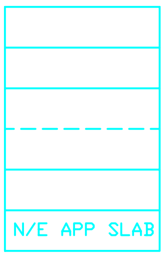
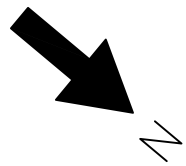
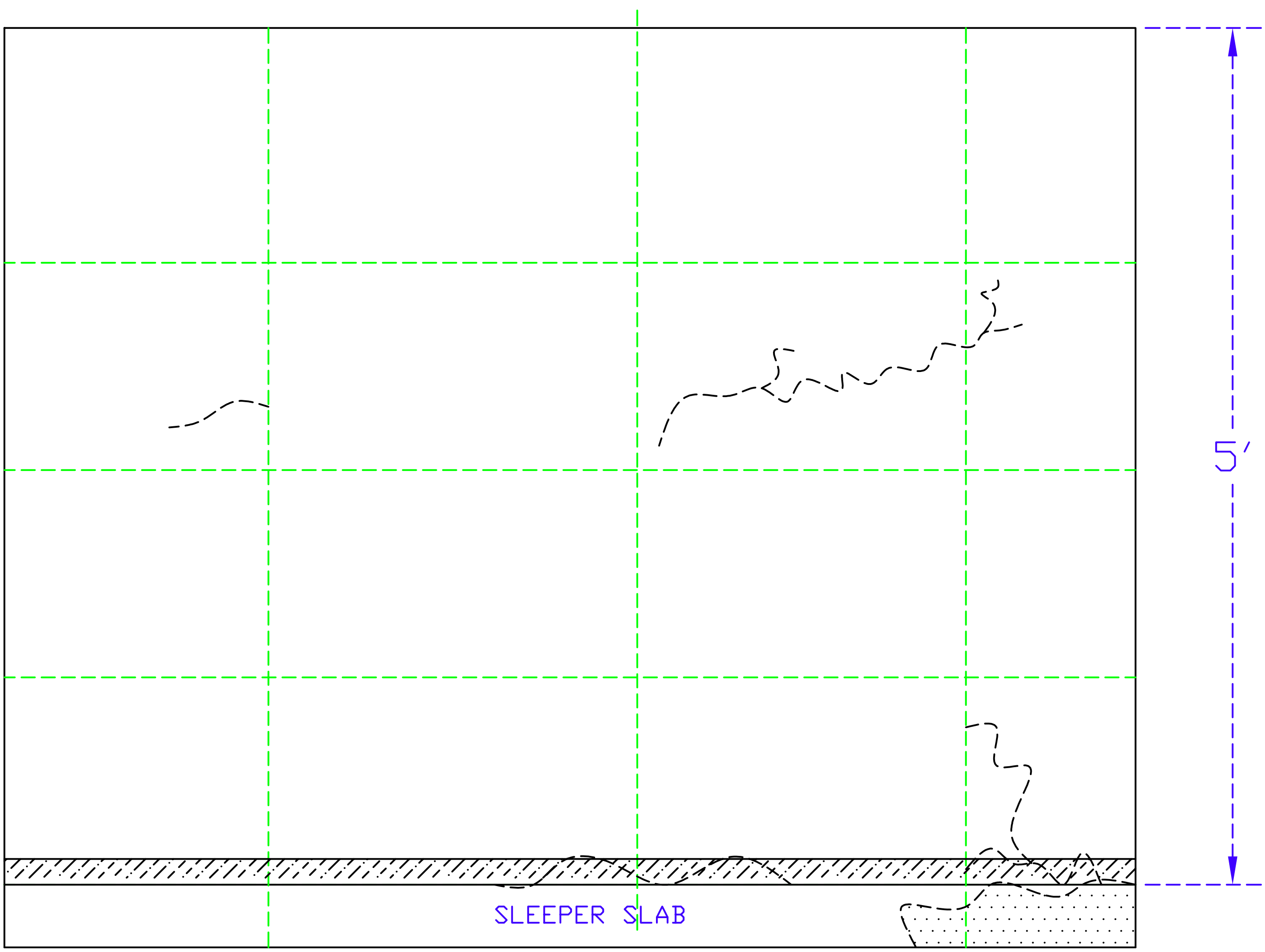
FIELD INSPECTION TEMPLATE

Bridge ID: S12-4 of 25042





N/E APPROACH SLAB



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FIELD INSPECTION TEMPLATE
Bridge ID: S12-4 of 25042

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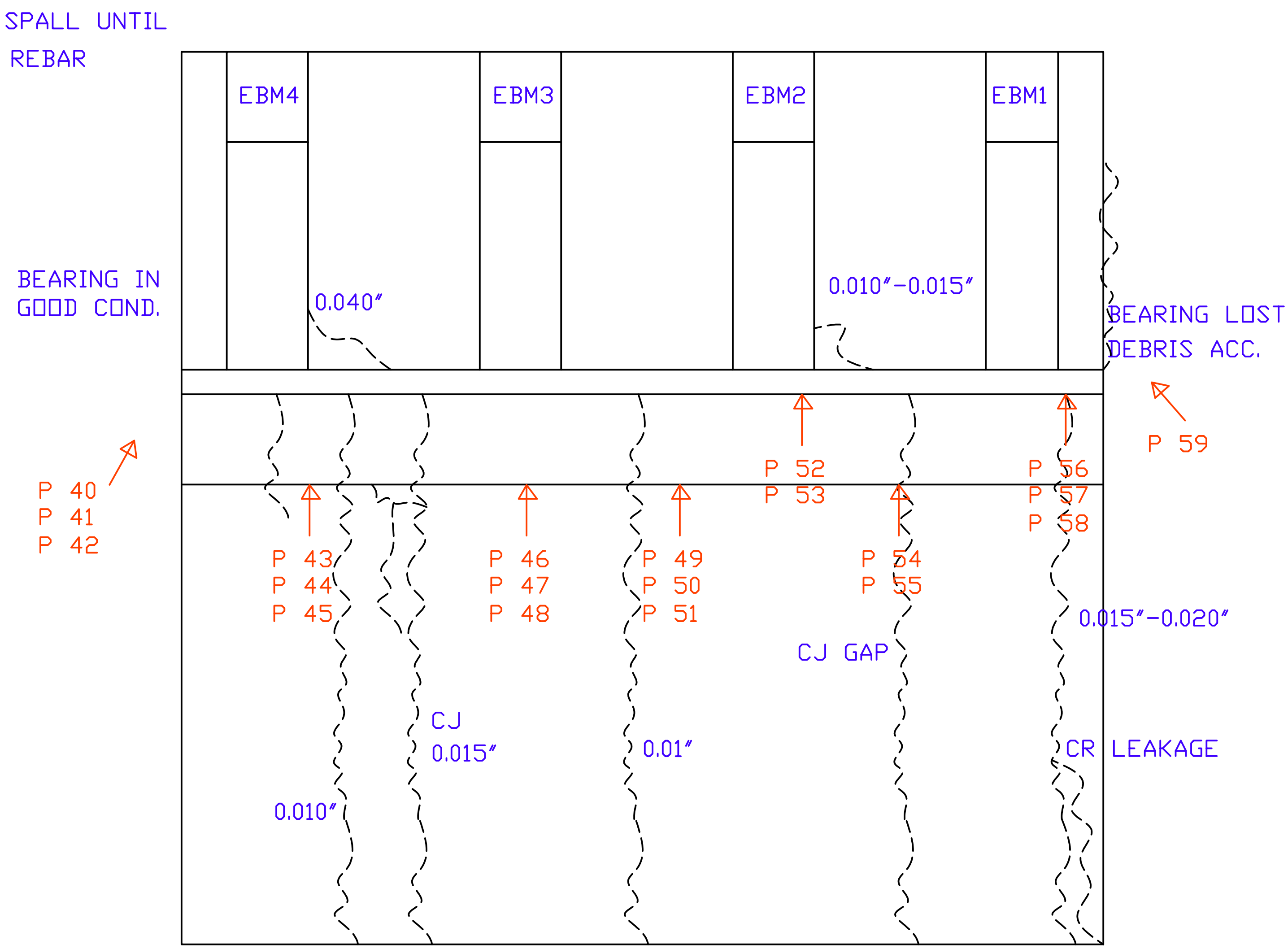
N/E ABUTMENT



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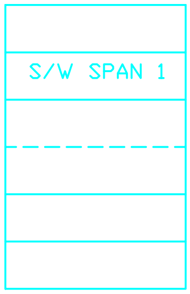
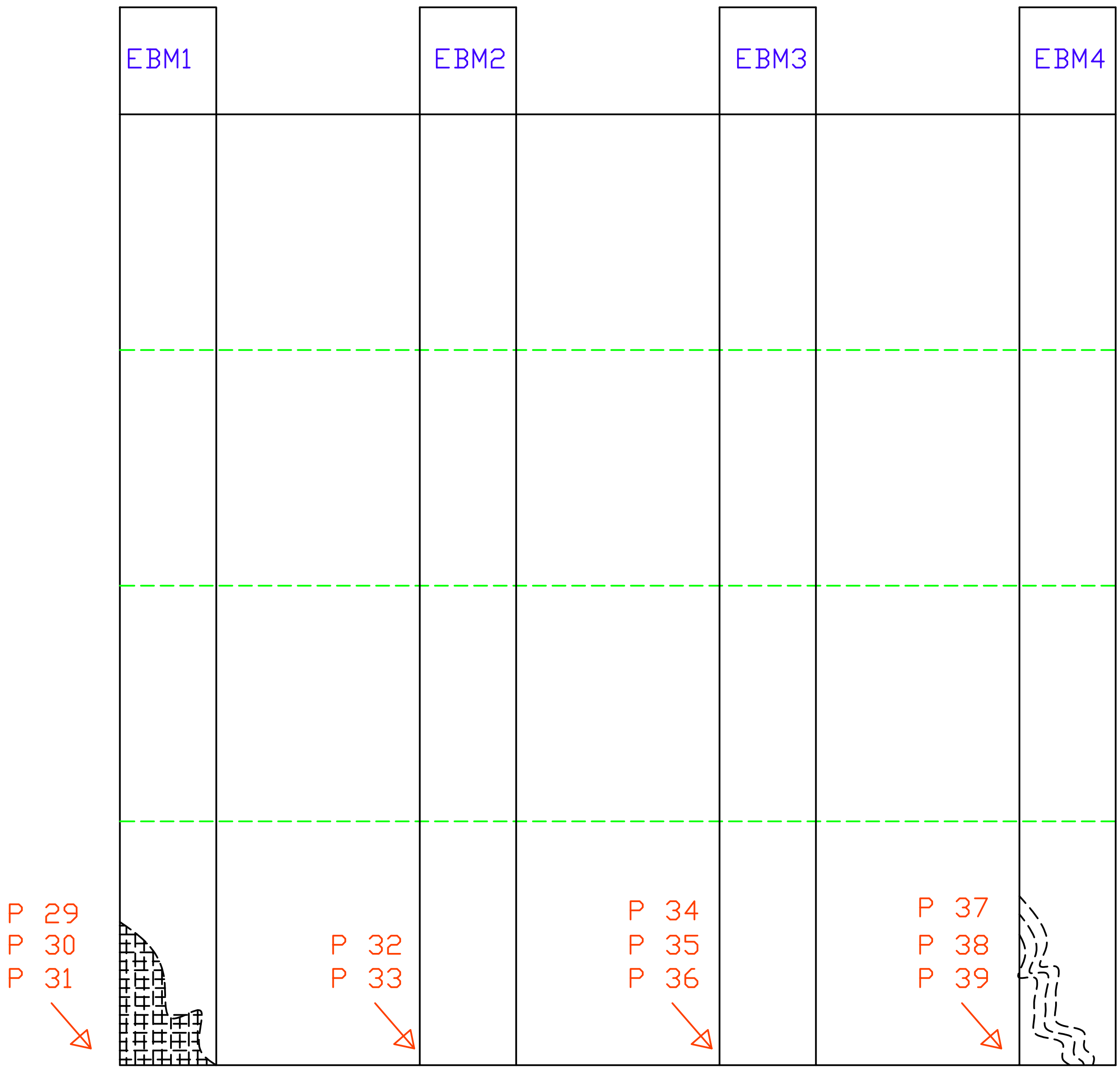
FIELD INSPECTION TEMPLATE

Bridge ID: S12-4 of 25042



BEAM S/W SPAN 1



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FIELD INSPECTION TEMPLATE

Bridge ID: S12-4 of 25042

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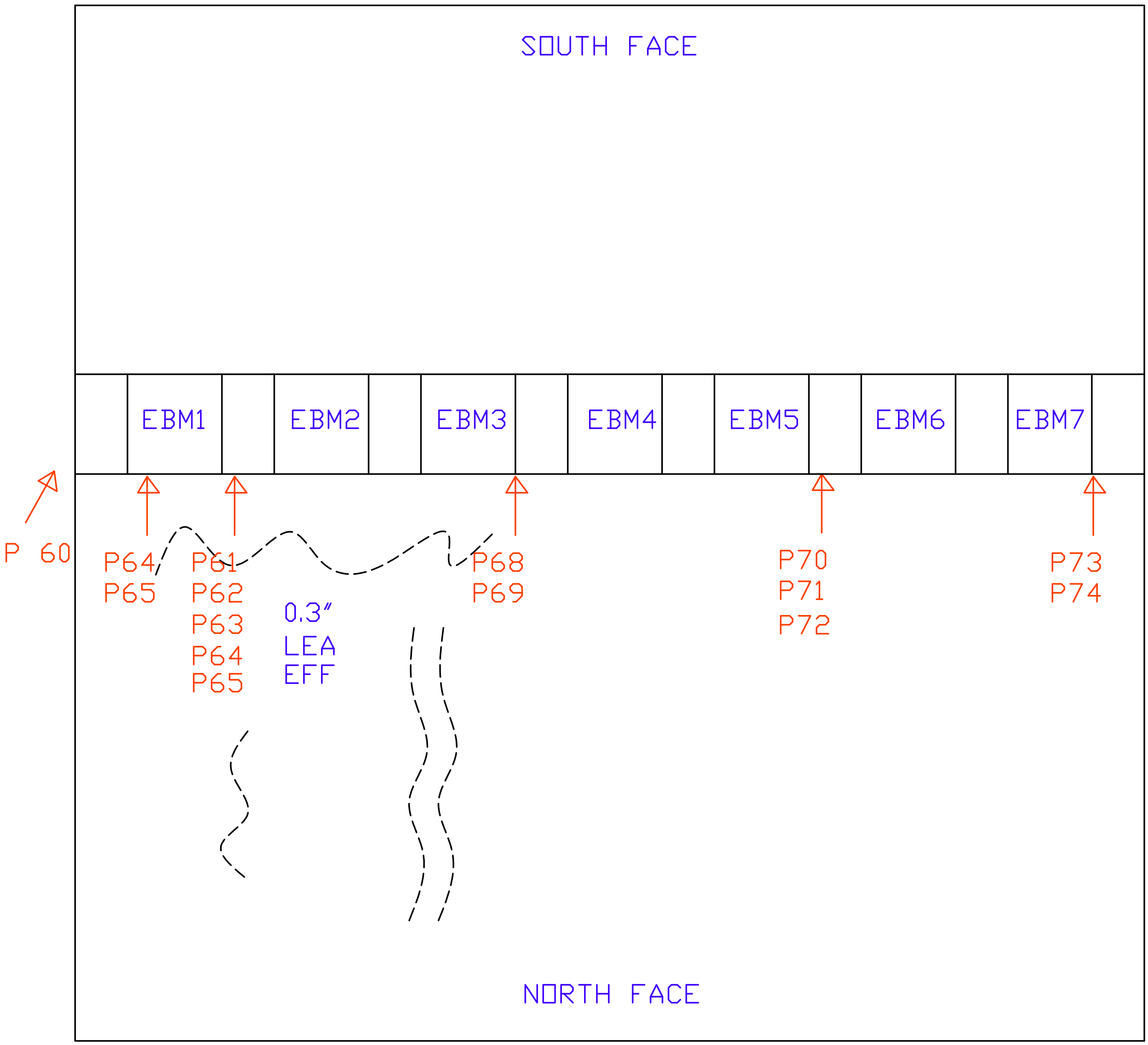
PIER 3



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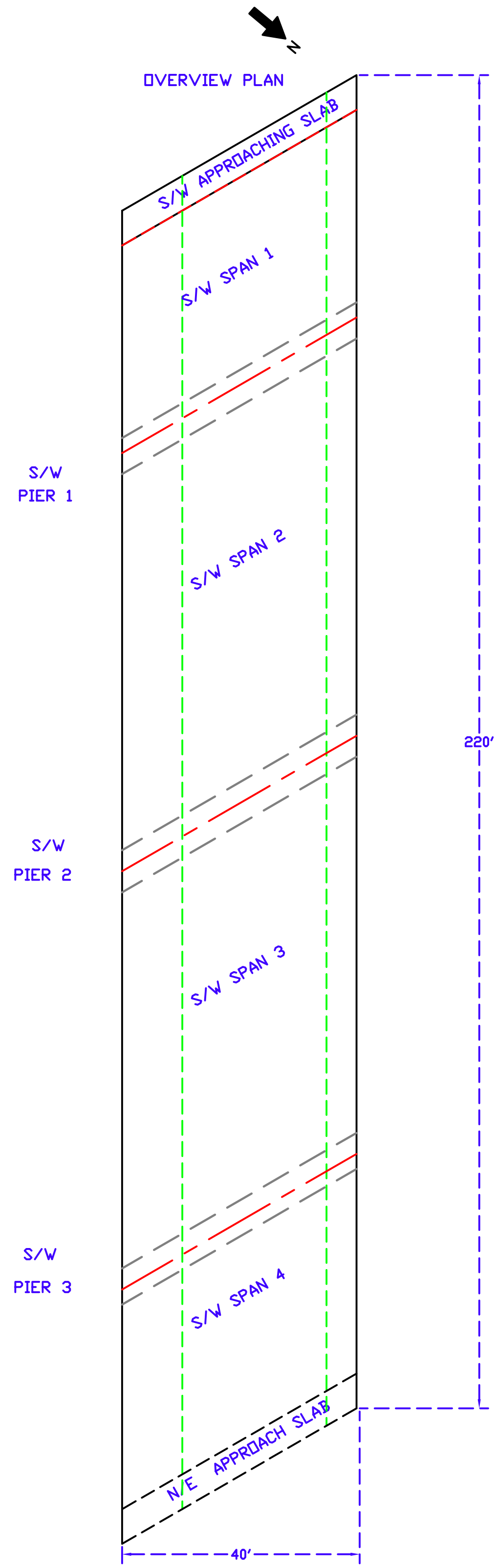
FIELD INSPECTION TEMPLATE

For S12-7 OF 25042 I-69 RAMP EB OVER I-75, GENESEE COUNTY, BAY REGION



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FIELD INSPECTION TEMPLATE

Bridge ID: S12-7 of 25042

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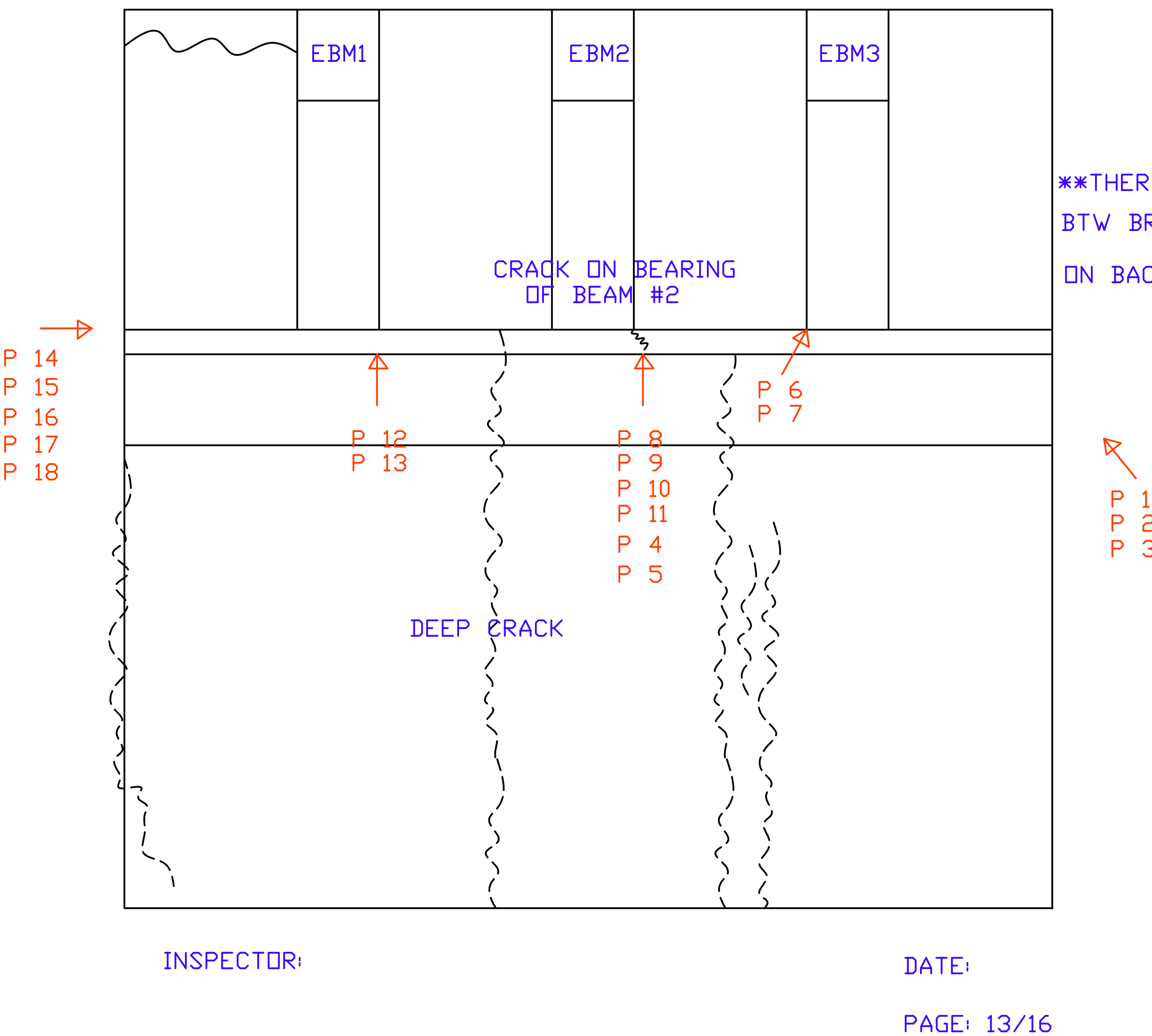
S/ W ABUTMENT



**THERE IS CRACKING
BTW BRIDGE 1 & 2
ON BACKWALL

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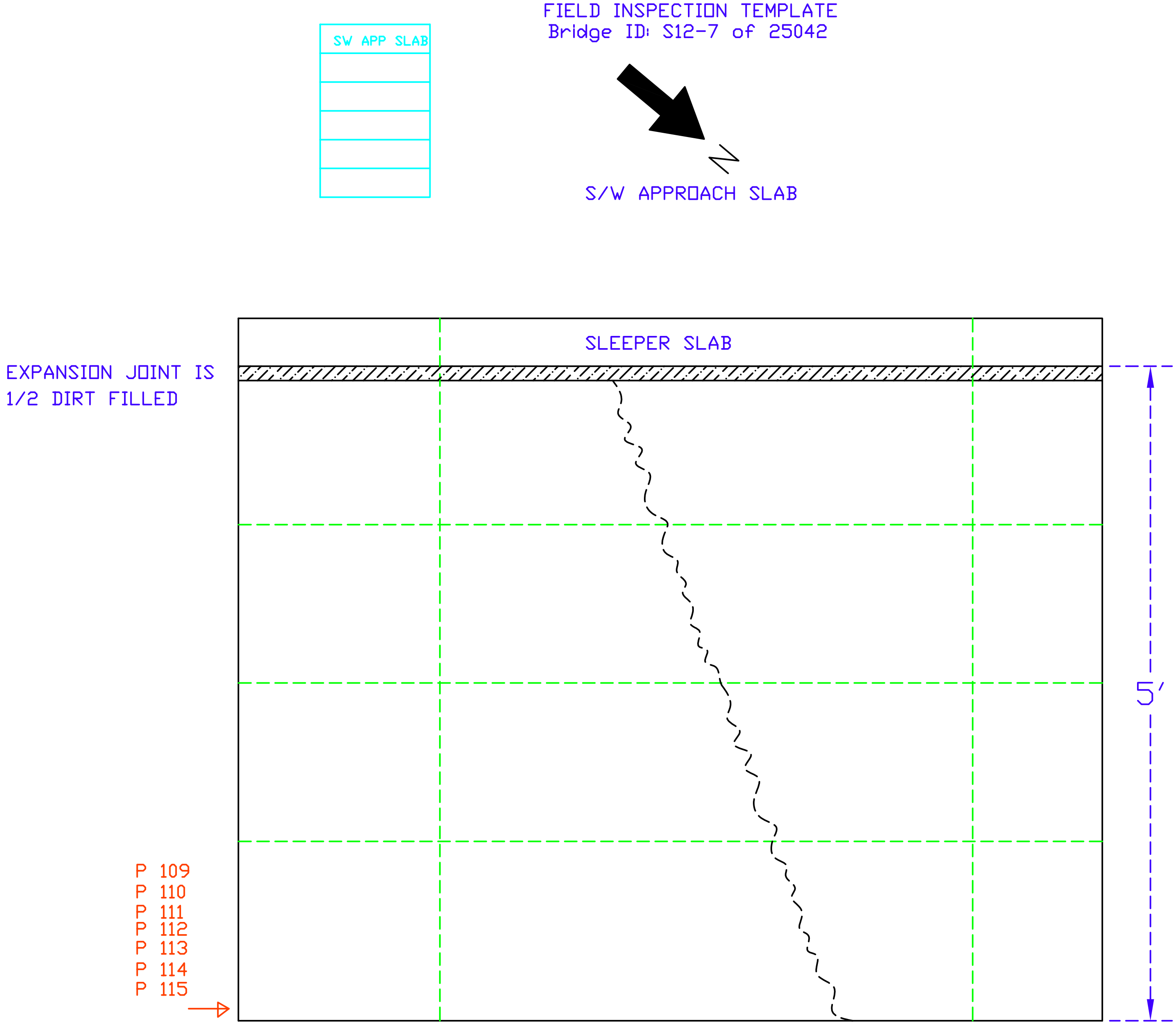
FIELD INSPECTION TEMPLATE
Bridge ID: S12-7 of 25042



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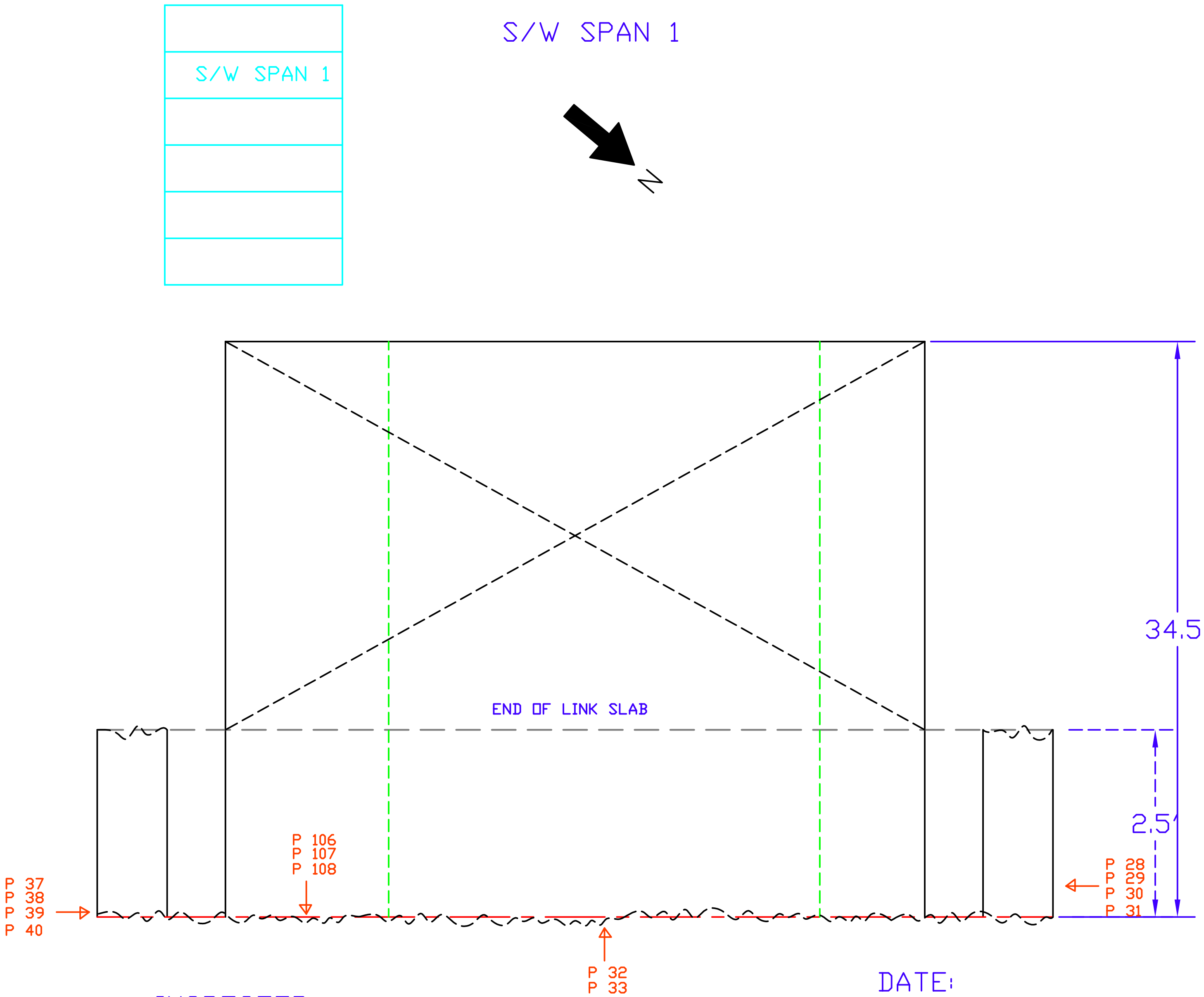
FIELD INSPECTION TEMPLATE
Bridge ID: S12-7 of 25042

BRIDGE DECK

S/W SPAN 1



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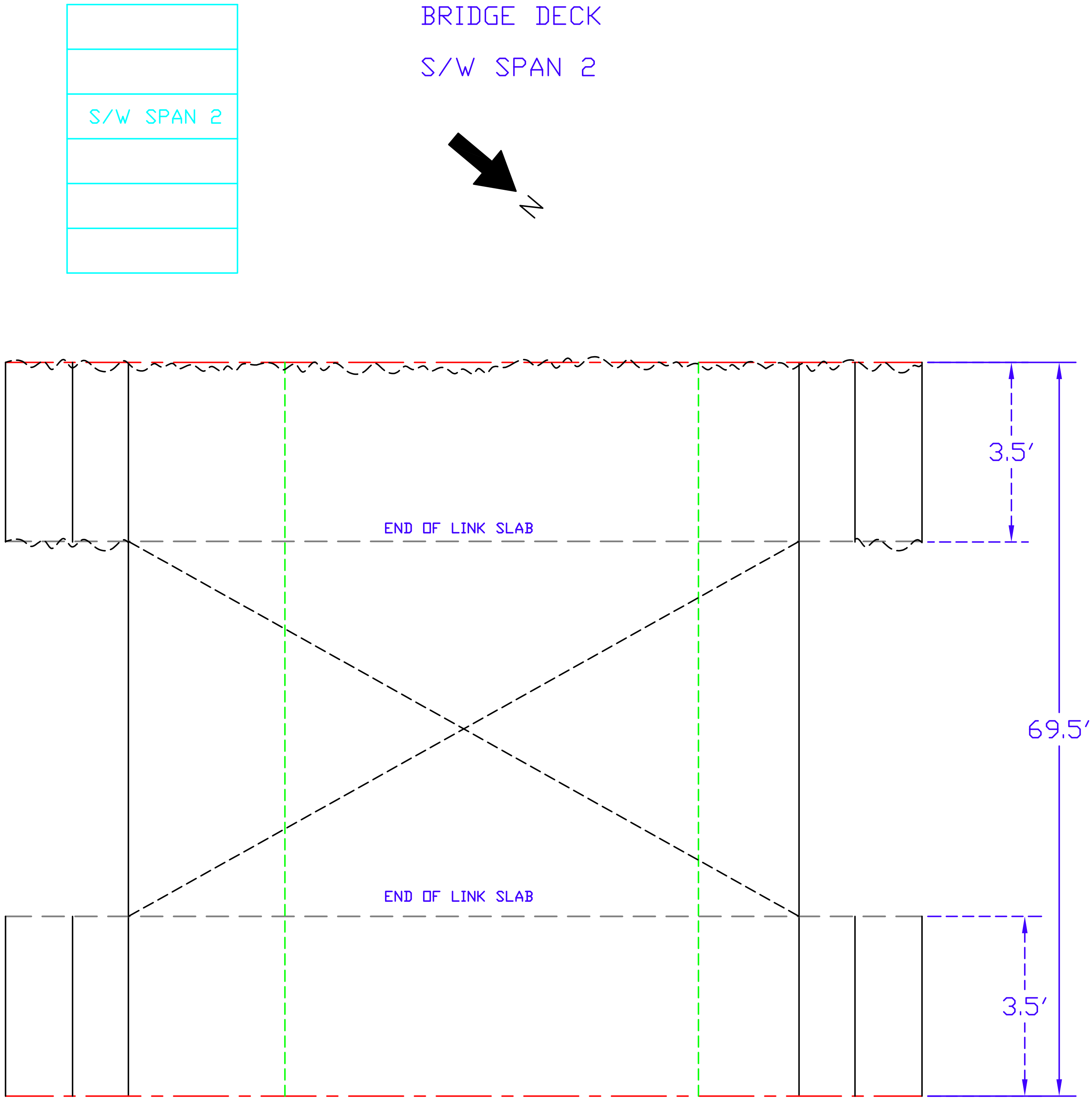
FIELD INSPECTION TEMPLATE
Bridge ID: S12-7 of 25042

BRIDGE DECK

S/W SPAN 2



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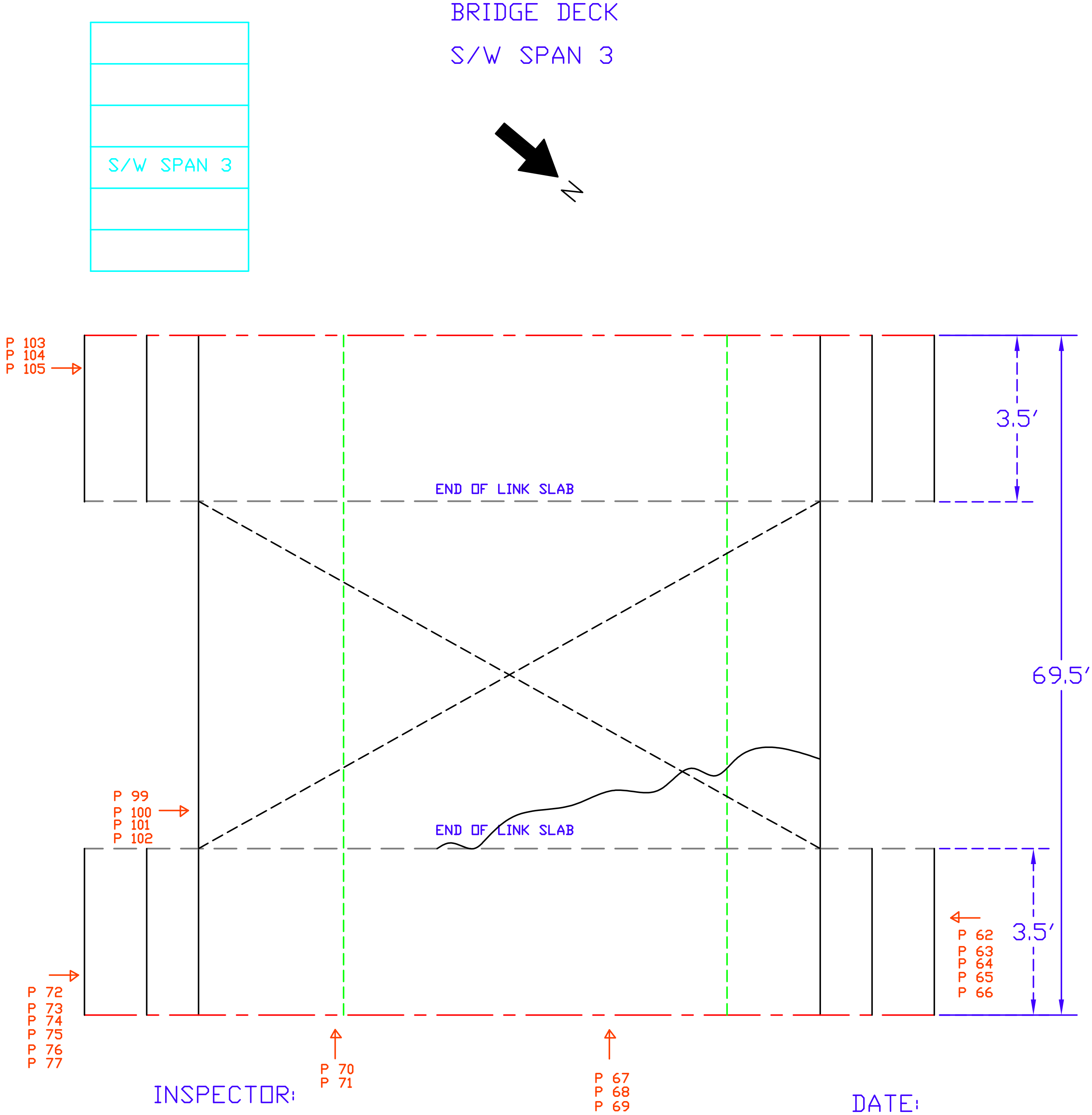
FIELD INSPECTION TEMPLATE
Bridge ID: S12-7 of 25042

BRIDGE DECK

S/W SPAN 3



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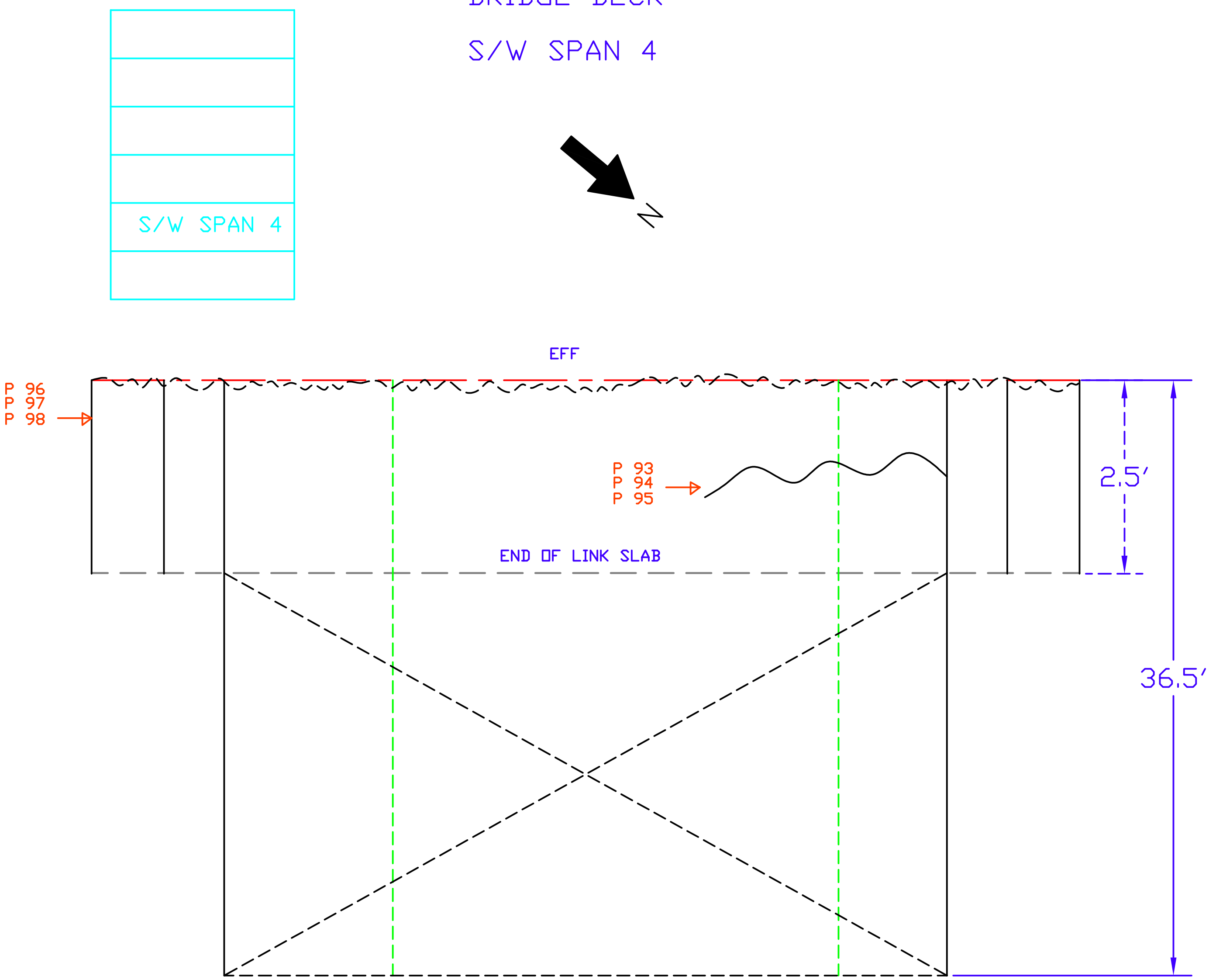
FIELD INSPECTION TEMPLATE
Bridge ID: S12-7 of 25042

BRIDGE DECK

S/W SPAN 4



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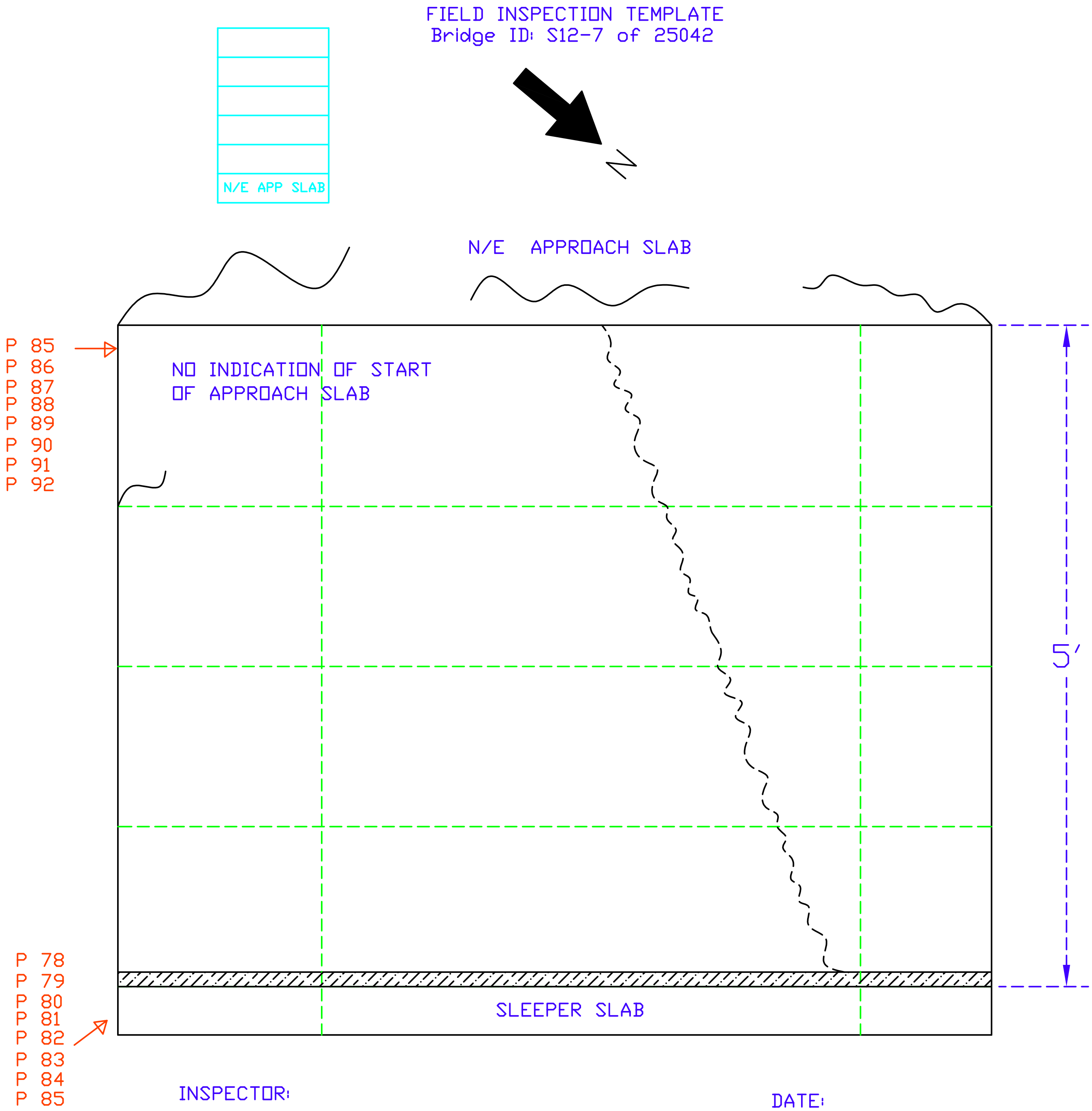
FIELD INSPECTION TEMPLATE
Bridge ID: S12-7 of 25042
N/E APP SLAB
N
N/E APPROACH SLAB
NO INDICATION OF START
OF APPROACH SLAB
P 85
P 86
P 87
P 88
P 89
P 90
P 91
P 92
5'
SLEEPER SLAB
P 78
P 79
P 80
P 81
P 82
P 83
P 84
P 85
INSPECTOR:
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FIELD INSPECTION TEMPLATE

Bridge ID: S12-7 of 25042

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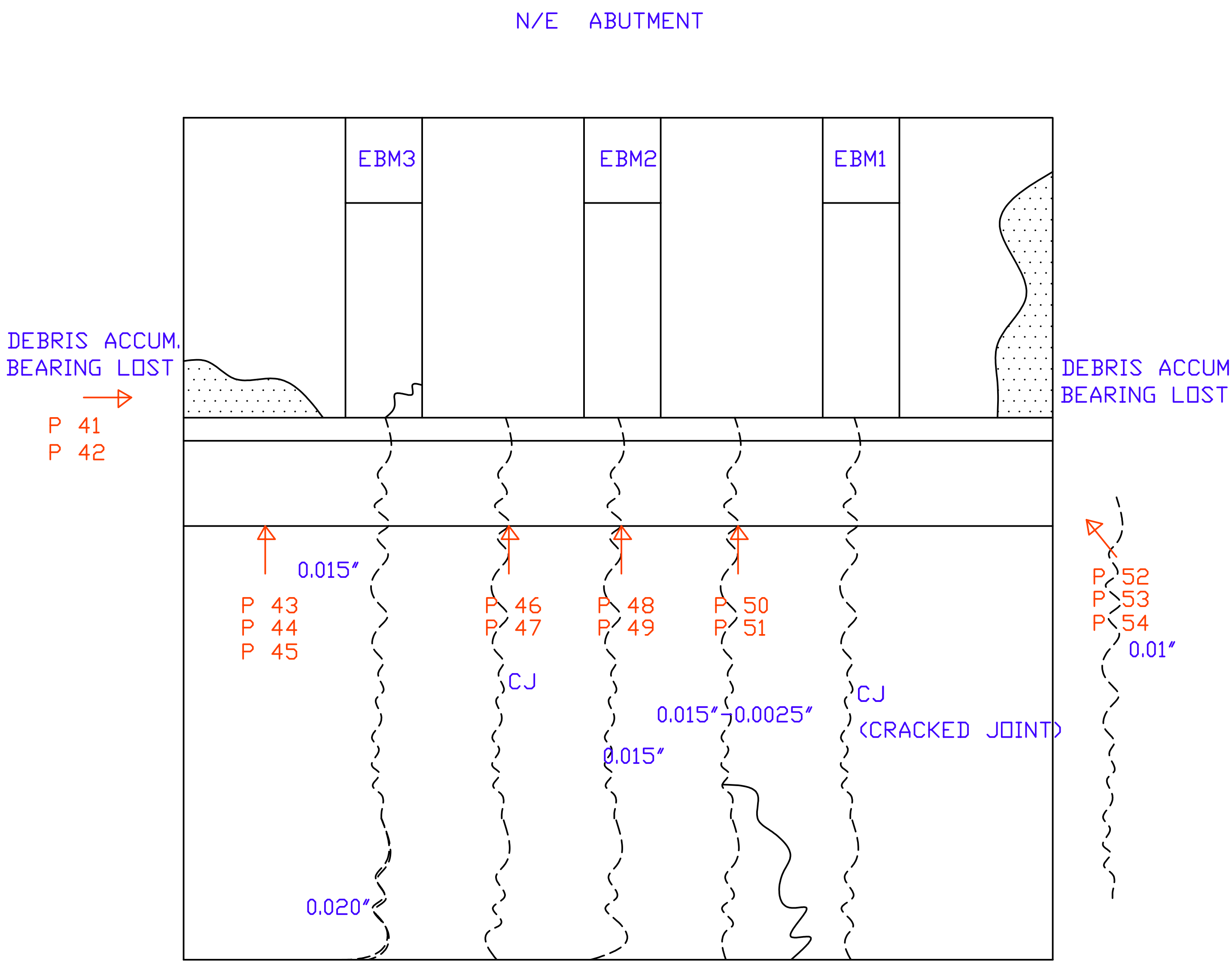

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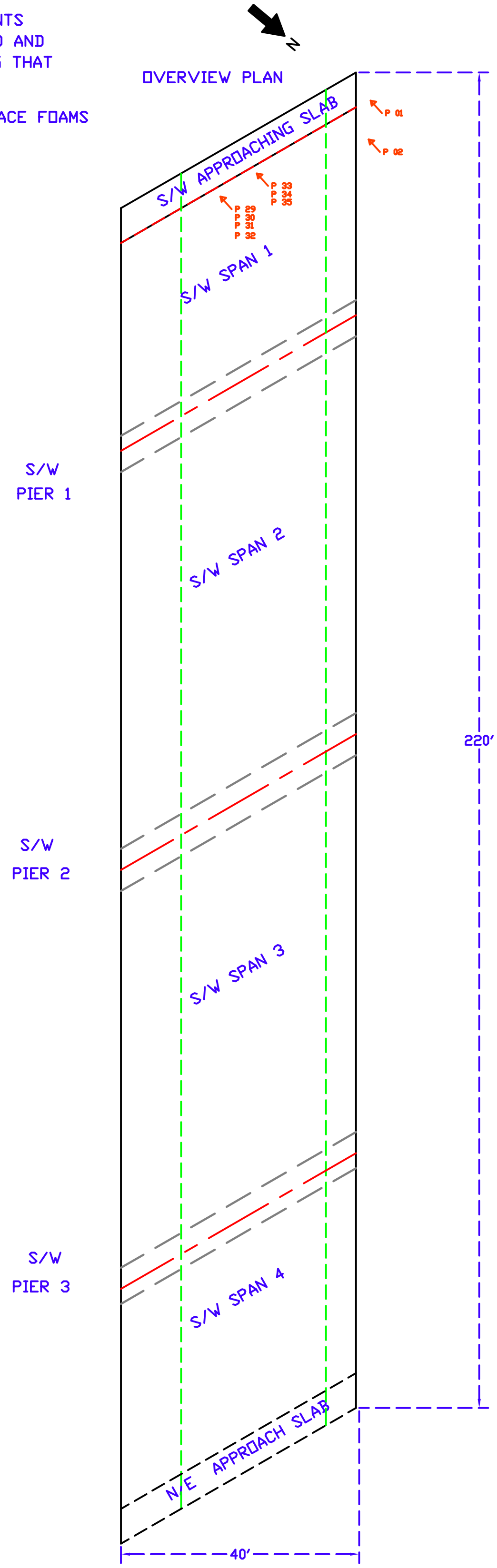
FIELD INSPECTION TEMPLATE

FOR S12-8 OF 25042 ON I-69 RAMP WB OVER I-75 , GENESEE COUNTY, BAY REGION

**EXPANSION JOINTS ARE DIRT-FILLED AND CRACKS SHOWING THAT THEY WORK

**NO STAY-IN-PLACE FOAMS

**ONLY ONE LANE OF TRAFFIC



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FIELD INSPECTION TEMPLATE

Bridge ID: S12-8 of 25042

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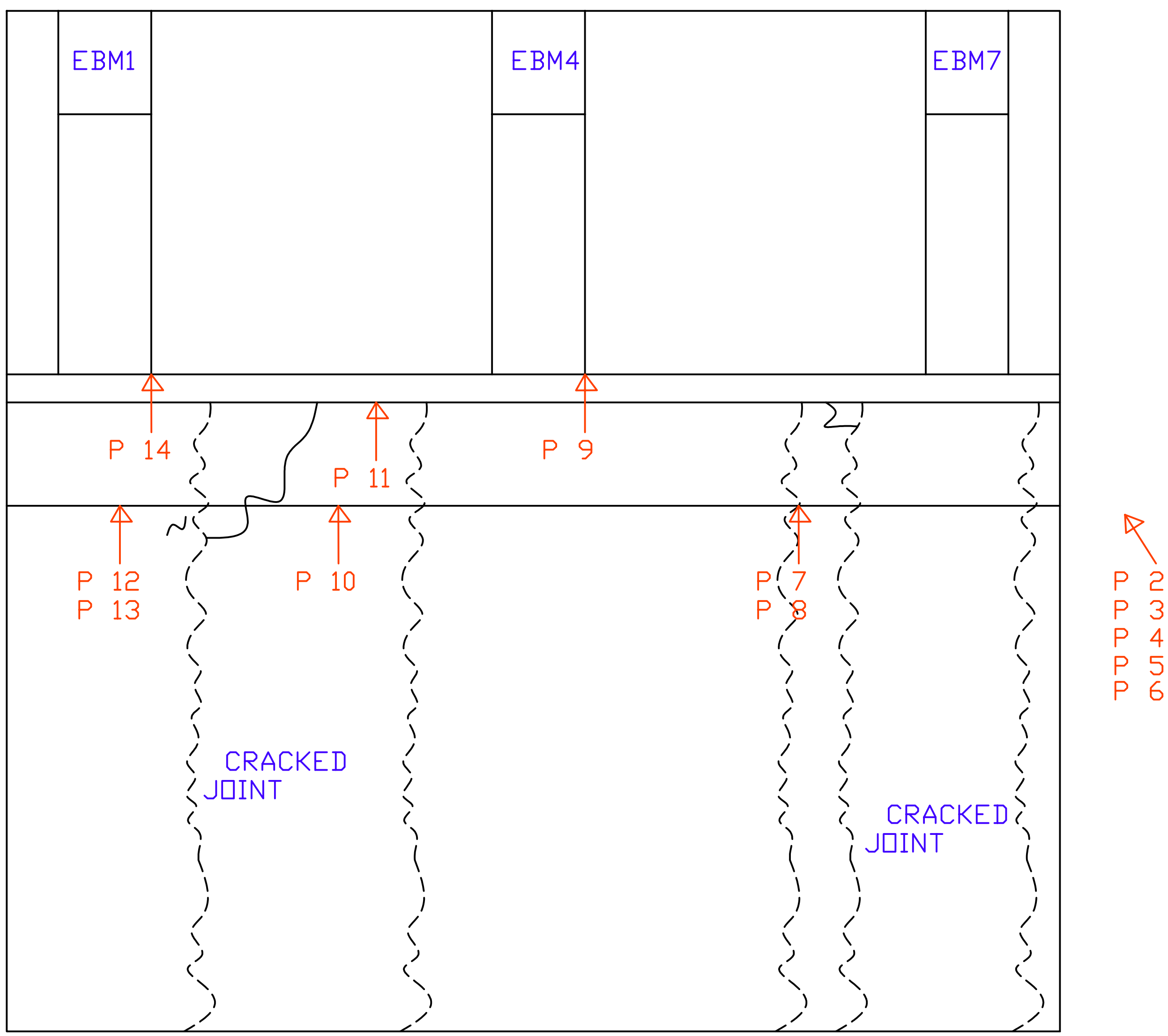
S/ W ABUTMENT



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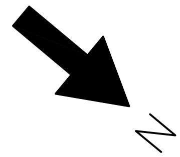
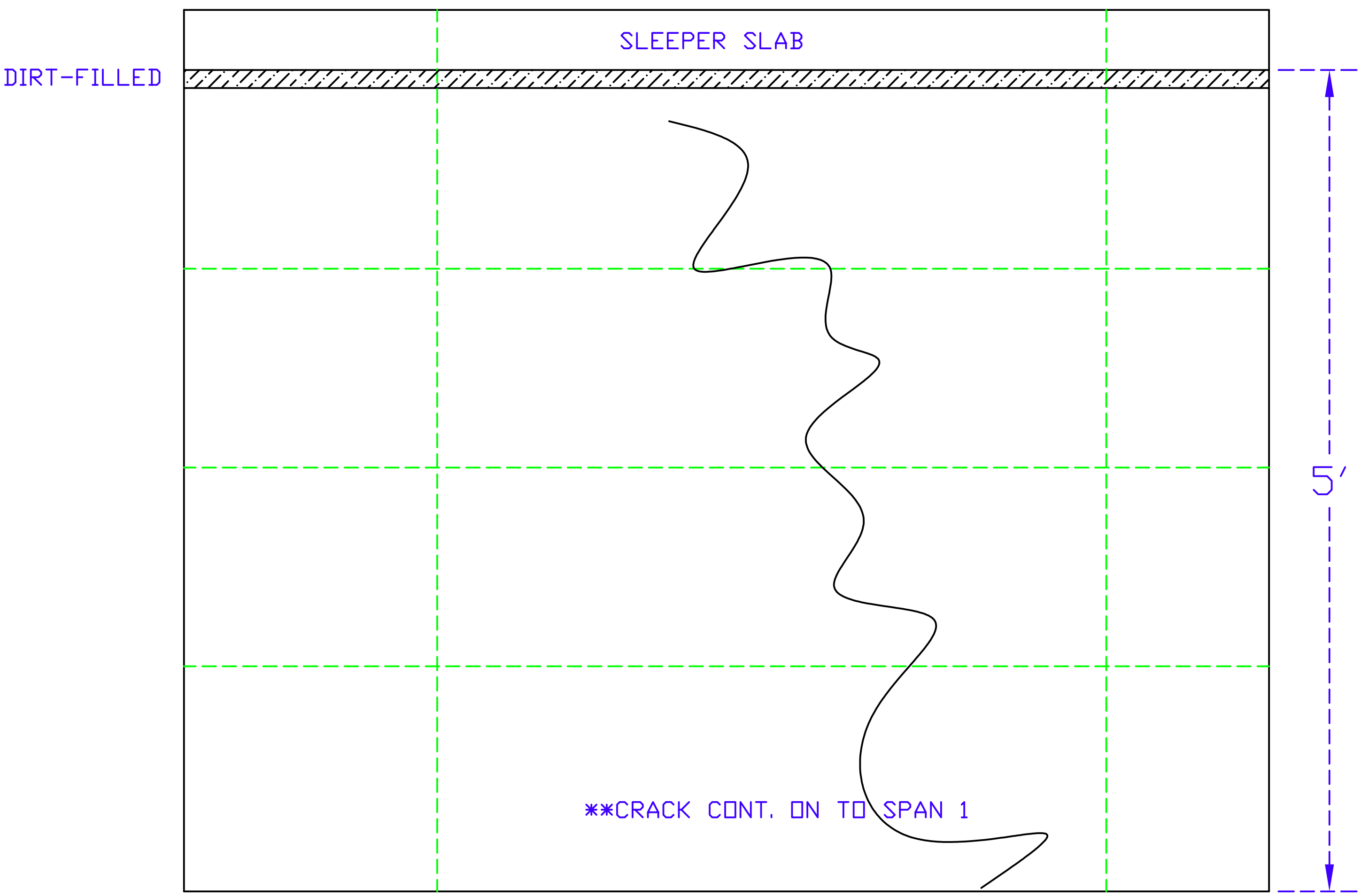
FIELD INSPECTION TEMPLATE

Bridge ID: S12-8 of 25042

SW APP SLAB



S/W APPROACH SLAB



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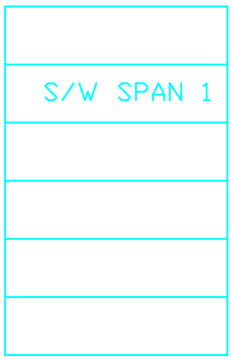
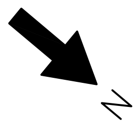
FIELD INSPECTION TEMPLATE

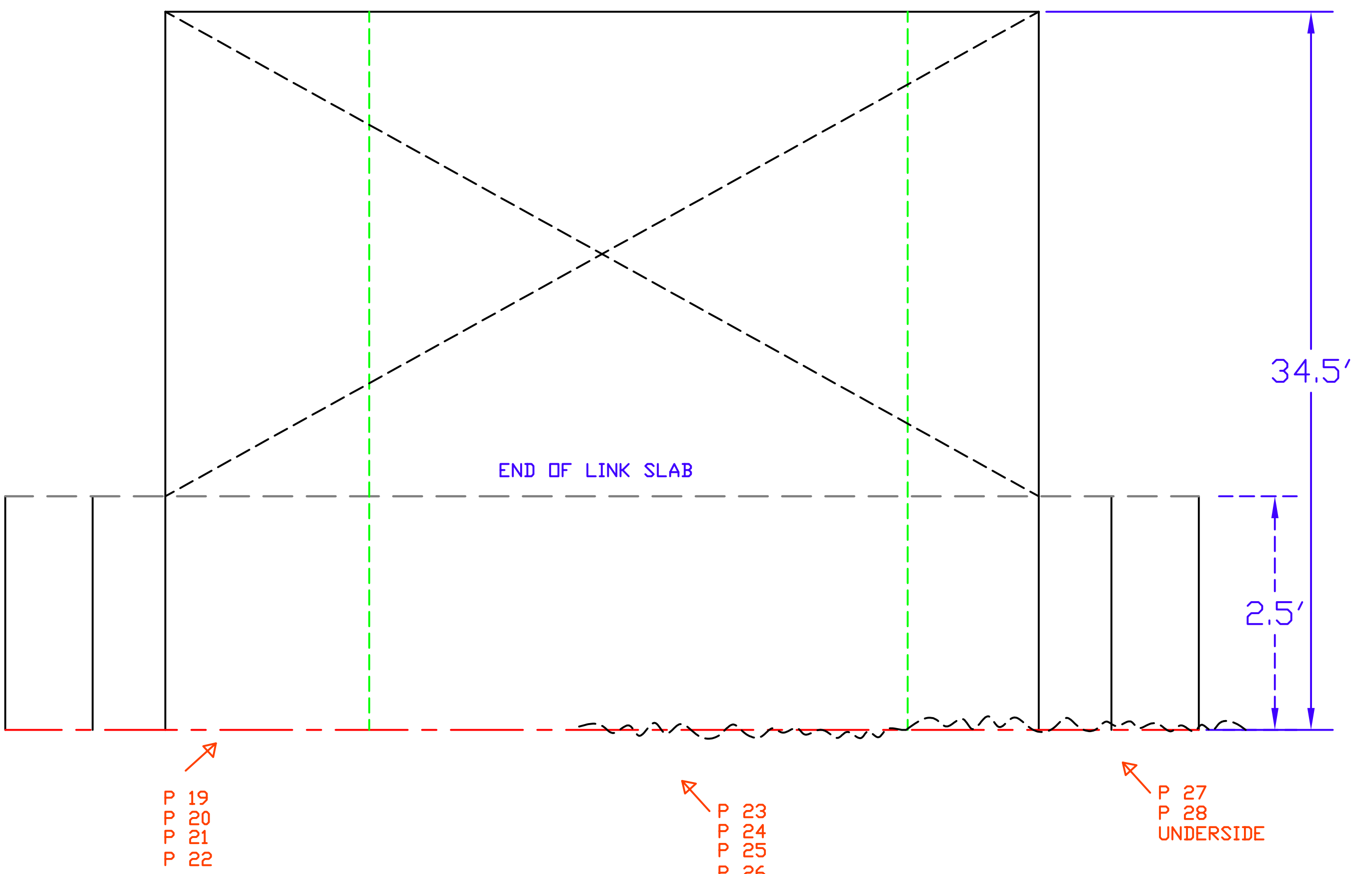
Bridge ID: S12-8 of 25042

BRIDGE DECK

S/W SPAN 1







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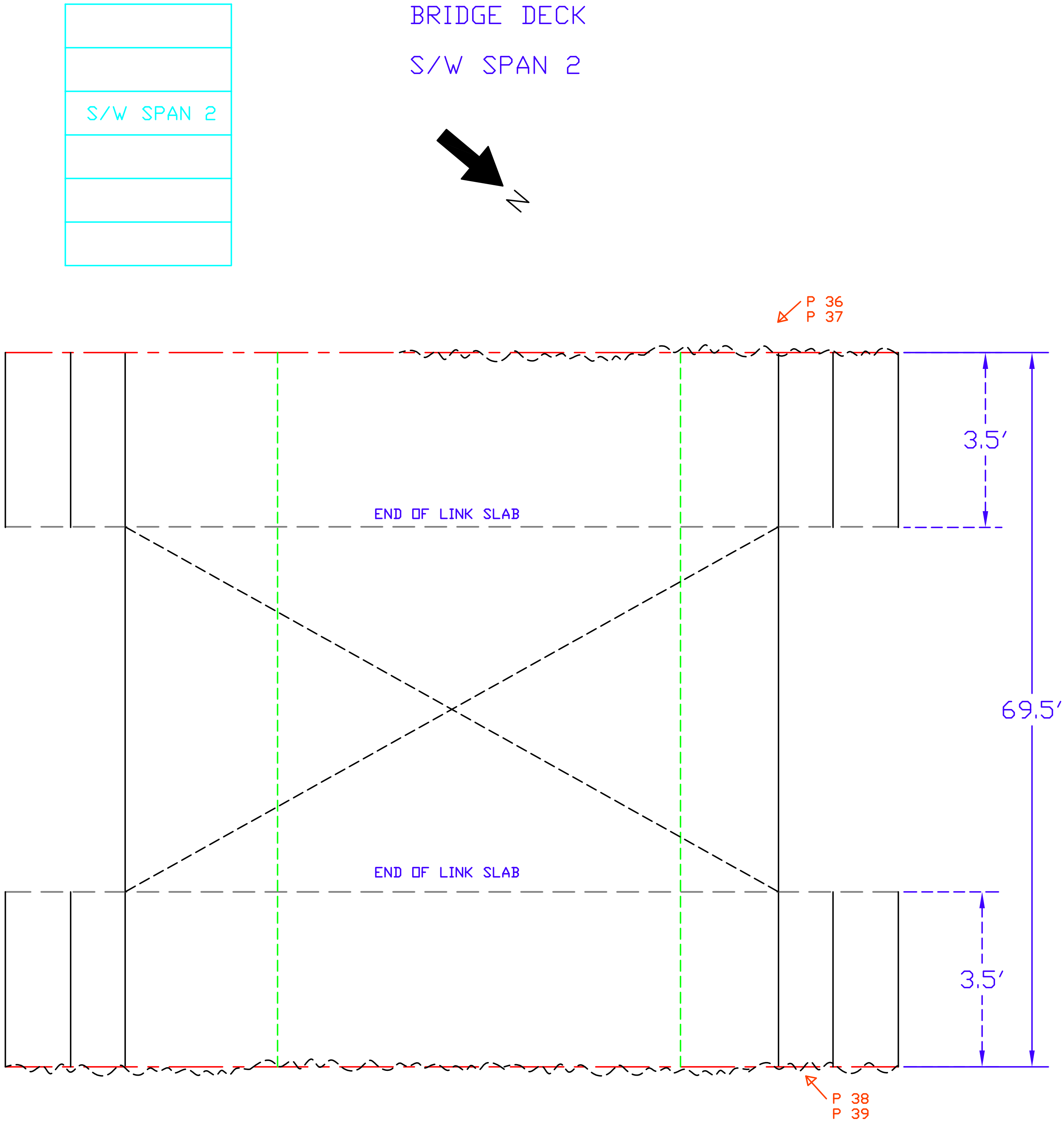
FIELD INSPECTION TEMPLATE
Bridge ID: S12-8 of 25042

BRIDGE DECK

S/W SPAN 2



INSPECTOR:

DATE:

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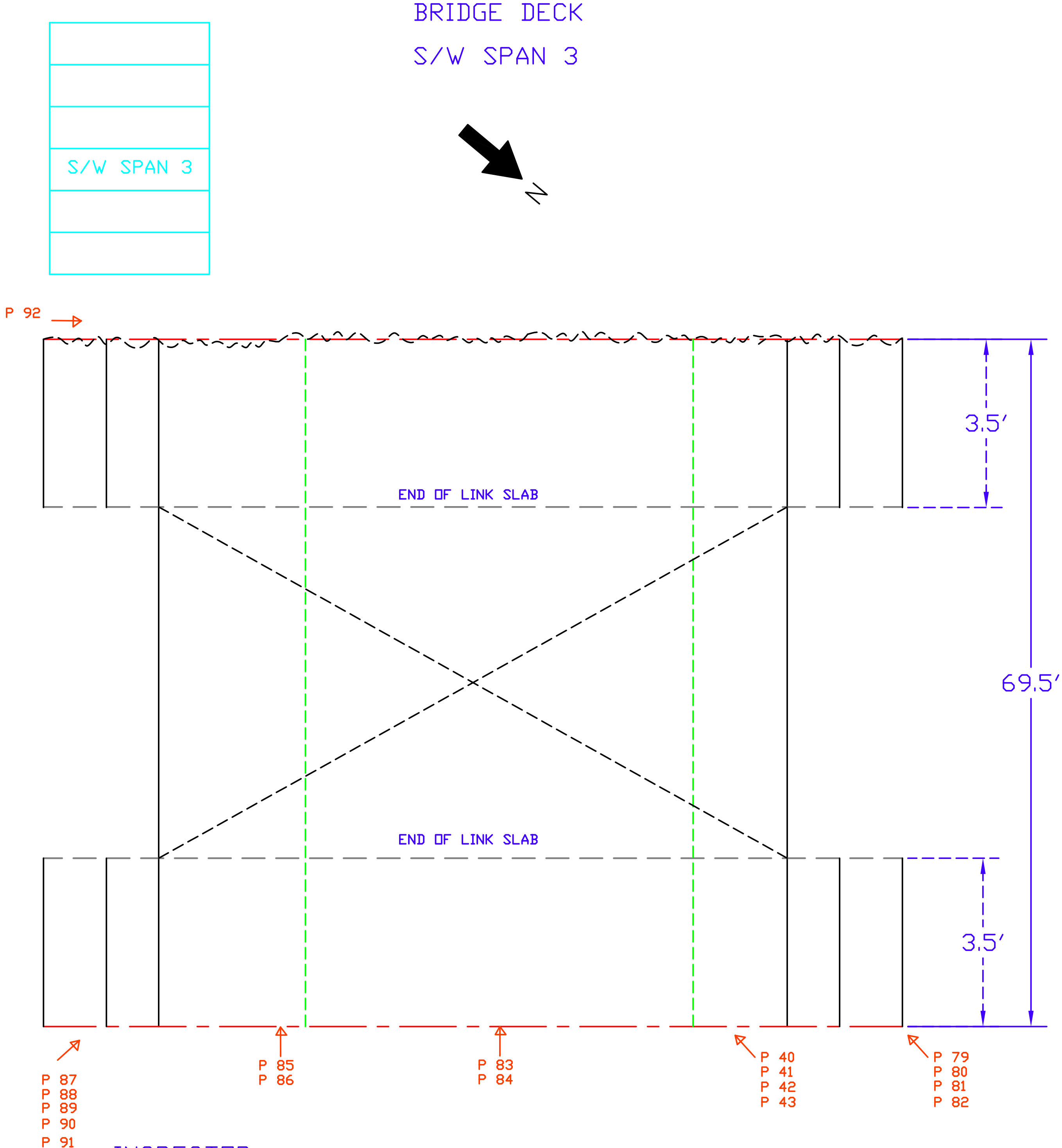
FIELD INSPECTION TEMPLATE
Bridge ID: S12-8 of 25042

BRIDGE DECK

S/W SPAN 3



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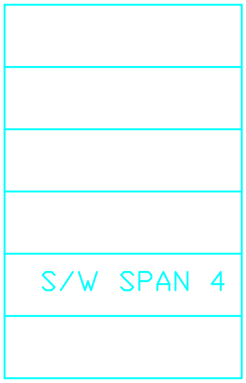
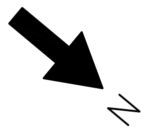
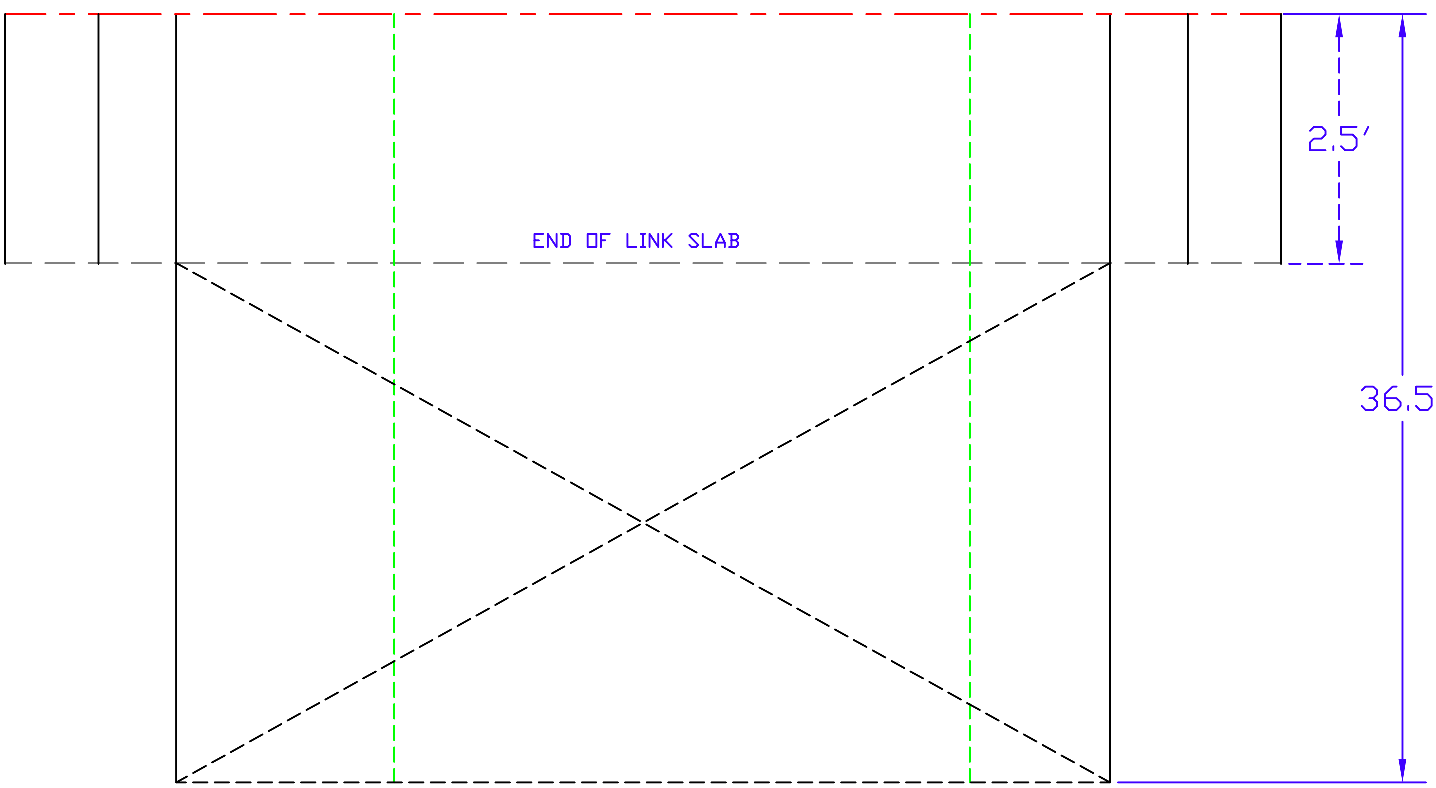
FIELD INSPECTION TEMPLATE
Bridge ID: S12-8 of 25042
BRIDGE DECK

S/W SPAN 4







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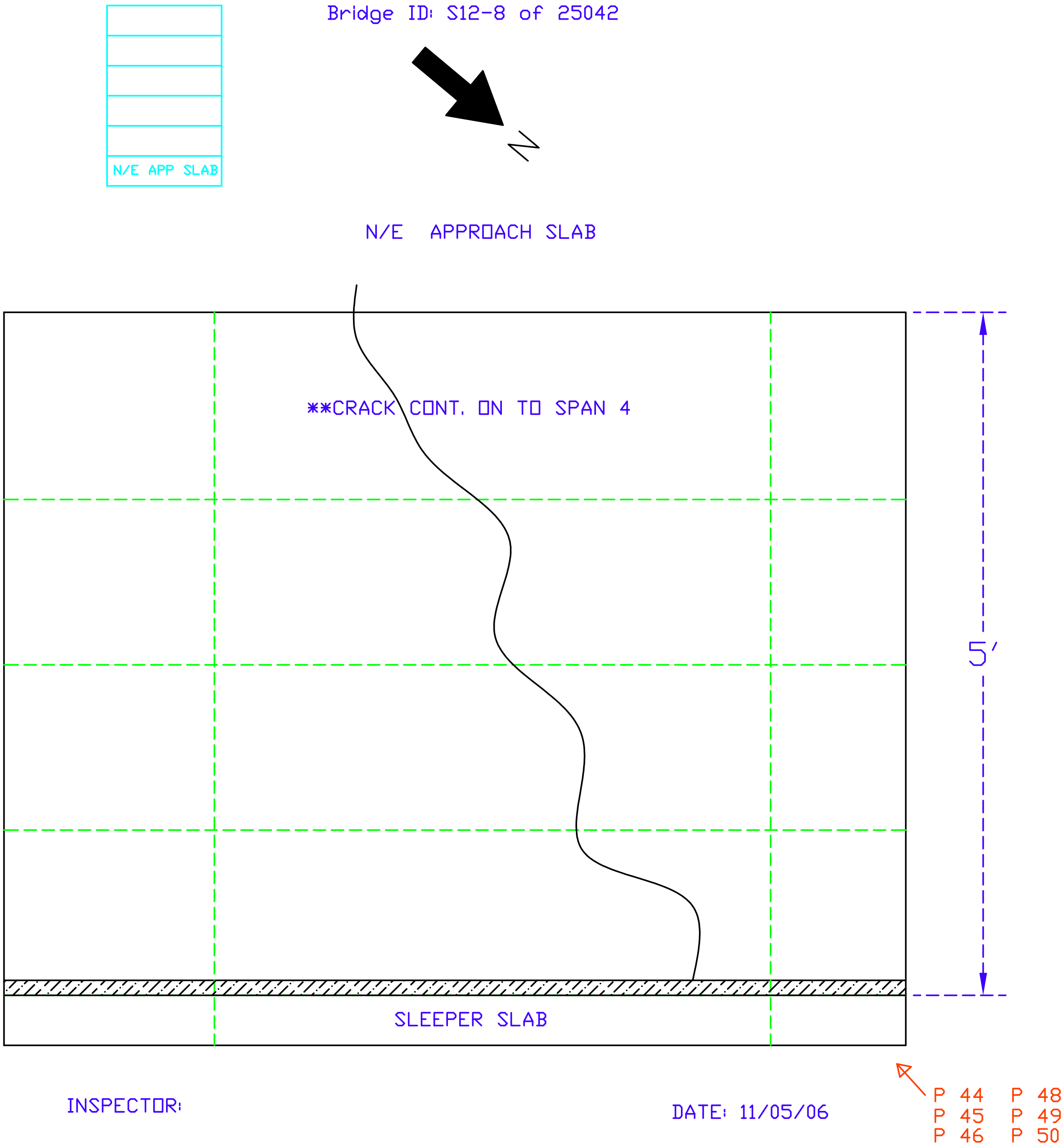
FIELD INSPECTION TEMPLATE
Bridge ID: S12-8 of 25042



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FIELD INSPECTION TEMPLATE

Bridge ID: S12-8 of 25042

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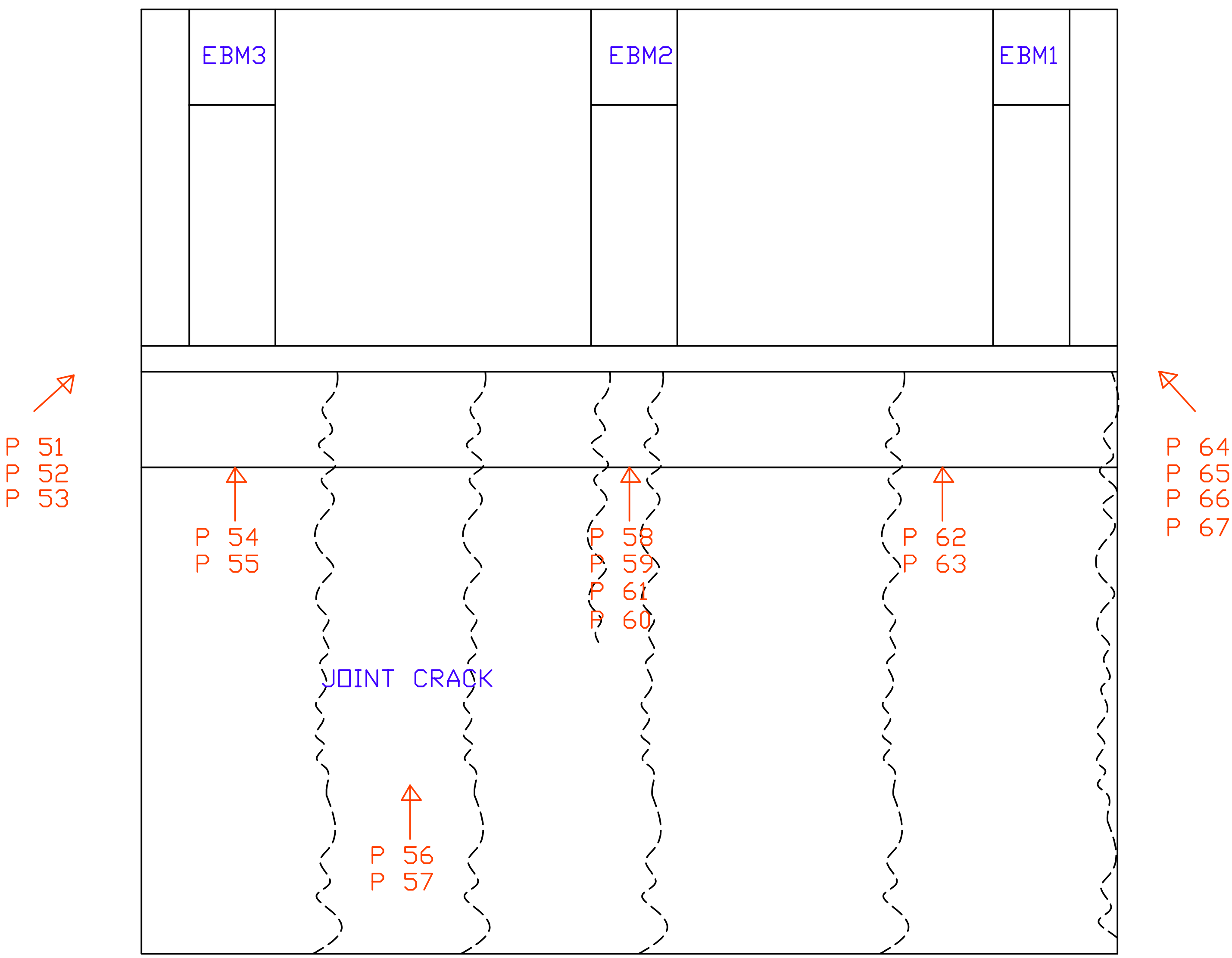
N/E ABUTMENT



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APPENDIX C

(a) I-75 over 13 Mile Road

North Bound

South Bound

Photo C - 1. I-75 over 13 mile road

(a) Saw cut on the link slab above the pier centerline

(b) Full depth link slab cracks – deck overhang

North Bound South Bound

Photo C - 2. Link slab condition

North Bound South Bound

(a) Debris filled expansion joint

North Bound South Bound

(b) Cracks on debris filled expansion joint

Photo C - 3. Expansion joint condition

North Bound South Bound

Photo C - 4. Diagonal cracking at the bridge deck corner

Photo C - 5. Sleeper slab condition (I-75 south bound)

Photo C - 6. Abutment condition of I-75 north bound

Photo C - 7. Abutment condition of I-75 south bound

(b) S08 of 41027 (I-196 EB over Monroe Ave)

Photo C - 8. I-196 EB over Monroe avenue

(a) (b)

Photo C - 9. (a) Bridge deck underside and (b) link slab underside

Photo C - 10. Abutment wall cracking

Photo C - 11. Deformed bearing

(c) B01 of 10042 (M-115 over Betzie river)

Photo C - 12. M-115 over Betzie river

Photo C - 13. Link slab cracking

Photo C - 14. Approach slab cracking

Photo C - 15. Expansion joints

(a) Abutment wall (b) Backwall

Photo C - 16. Cracking of (a) abutment wall and (b) backwall

(d) S12-3, 4 of 25042 (I-69 EB and WB over I-75)

Photo C - 17. I – 69 EB and WB bridges and EB and WB ramp bridges

(a) I – 69 EB (b) I – 69 WB

Photo C - 18. Link slab condition of I – 69 (a) EB and (b) WB

Photo C - 19. Saw cut provided on the link slab over the pier (I-69 EB)

Photo C - 20. Approach slab cracking over the abutment (I-69 EB)

Photo C - 21. Debris filled joint with cracks (I-69 EB)

Photo C - 22. Transverse and diagonal cracks on I-69 EB bridge deck

(a) I-69 EB (b) I-69 WB

Photo C - 23. Abutment and pier cap conditions

(e) S12-7, 8 of 25042 (I-69 EB and WB ramps over I-75)

(a) I – 69 EB Ramp (b) I – 69 WB Ramp

Photo C - 24. Link slab condition (a) I-69 EB ramp and (b) I-69 WB ramp

(a) I – 69 EB Ramp (b) I – 69 WB Ramp

Photo C - 25. Saw cut on link slab over the piers

(a) I – 69 EB Ramp (b) I – 69 WB Ramp

Photo C - 26. Approach slab condition of I-69 (a) EB ramp and (b) WB ramp

(a) I – 69 EB Ramp (b) I – 69 WB Ramp

Photo C - 27. Expansion joint condition of I-69 (a) EB ramp and (b) WB ramp

(a) I – 69 EB Ramp (b) I – 69 WB Ramp

Photo C - 28. Abutment wall condition of I-69 (a) EB ramp and (b) WB ramp

(a) I – 69 EB Ramp (b) I – 69 WB Ramp

Photo C - 29. Backwall cracking at the vicinity of bearings

APPENDIX D

Table D-1. Inspector Comments on Abutment Condition of S04-1-63174

Inspection Date	Inspector Comments - Abutment Conditions	
	North Abutment	South Abutment
6/25/1999	Vertical cracks & incipient spall under beam 4W.	Vertical cracks & incipient spall under beam 2W.
6/30/2000	Vertical cracks & incipient spall under beam 4W.	Vertical cracks & incipient spall under beam 2W.
9/26/2001	Under Construction.	Under Construction.
2/25/2002	Vertical cracks. Incipient spall at beam 7W.	Patched areas on NE area. Vertical cracks.
2/24/2004	Vertical cracks. Incipient spall at beam 7W.	Patched areas on NE area. Vertical cracks.
2/17/2006	Vertical cracks. Incipient spall at beam 7W.	Patched areas on NE area. Vertical cracks.
12/3/2006	Abutment wall vertical cracks. Abutment wall vertical cracks under beams 1W, 3W, 4W, 8W. Beam 1W bottom flange delamination close to bearing. Abutment wall cracks, delamination and incipient spall at beam 7W.	Abutment wall vertical cracks under beams 2W, 3W, 4W, 6W, 7W, 8W. Abutment wall repair under bm 2W. Horizontal backwall crack near bearing bm 1W. Abutment wall D-cracks and incipient spall under beam 2W

<table>
<tr><th>North Abutment</th><th>South Abutment</th></tr>
<tr><td>

Crack in beam 1W

Vertical crack under bm 1W

Delamination, cracks, incipient spall, and patch work under beam 7W
</td><td>

Horizontal backwall crack at beam 1W

Abutment wall D-crack with incipient spall under beam 2W

Vertical crack under beam 7W
</td></tr>
</table>

Photo D-1. Abutment Distress of S04-01-63174

Table D-2. Inspector Comments on Abutment Condition of S04-2-63174

Inspection Date	Inspector Comments - Abutment Conditions	
	North Abutment	South Abutment
6/25/1999	Vertical cracks & incipient spall under beam 5W.	Repaired area under beam 5W.
6/30/2000	Vertical cracks & incipient spall under beam 5W.	Repaired area under beam 5W.
6/9/2001	No inspector comments.	No inspector comments.
3/13/2002	Patched and waterproofed. Crack under beam 1W.	Patched and waterproofed.
2/24/2004	Patched and waterproofed. Crack under beam 1W.	Patched and waterproofed.
2/17/2006	No inspector comments.	No inspector comments.
12/3/2006	Abutment wall vertical cracks. Abutment wall vertical cracks under beams 3W, 4W, and 7W. Horizontal backwall cracks near bearing of beam 3W. Abutment wall patched under beam 5W. Abutment wall D-cracks and incipient spall under beams 1W, 5W, and 6W.	Abutment wall vertical cracks. Abutment wall vertical cracks under beams 1W, 5W, 6W, 7W, and 8W. Abutment wall patched under beam 4W. Cracks and delamination on abutment wall under bm 4W. Cracks, delamination, and incipient spall under beam 5W. Horizontal backwall cracks near beam 9W bearing. Abutment wall D-cracks and incipient spall under beam 9W.

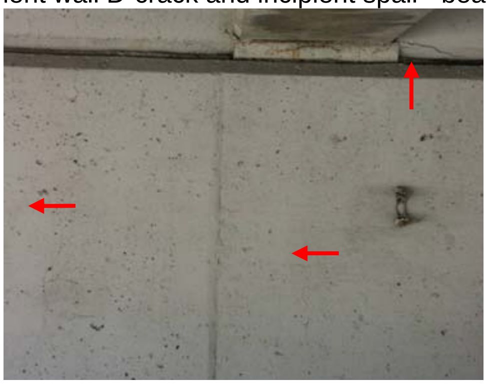
North Abutment	South Abutment
 Abutment wall D-crack and incipient spall - beam 1W	 Vertical crack under beam 1W
 Horizontal and vertical cracks at beam 3W	 Cracks and patch work at beam 4W. Horizontal backwall crack
 Abutment wall delamination and spall - beam 5W	 Delamination, incipient spall, and vertical crack under beam 5W.
 Abutment wall D-crack and incipient spall - beam 6W	 Abutment wall D-crack and backwall horizontal cracks at beam 9W

Photo D-2. Abutment Distress of S04-02-63174

Table D-3. Inspector Comments on Abutment Condition of S08 - 41027

Inspection Date	Inspector Comments - Abutment Conditions	
	Northwest Abutment	**Southeast Abutment**
9/24/1999	Backwall has horizontal leach crack. Below bearings, couple vertical cracks.	Couple wet areas in backwall. Below bearings, couple vertical cracks.
11/1/1999	Backwall has large vertical leach crack. Below bearings, couple vertical cracks.	Couple wet areas in backwall. Below bearings, couple vertical cracks.
11/30/2001	Backwall has large vertical leach crack. Below bearings, couple vertical cracks.	Couple wet areas in backwall. Below bearings, couple vertical cracks.
5/15/2003	Typical vertical cracks. Wet leaching cracks in top of backwalls.	Typical vertical cracks. Wet leaching cracks in top of backwalls.
4/13/2005	Typical vertical cracks. Wet leaching cracks in top of backwalls.	Typical vertical cracks. Wet leaching cracks in top of backwalls.
12/19/2005	Some abut repairs made 2005. Good Condition.	Some abut repairs made 2005. Good Condition.
11/4/2006	Abutment wall vertical cracks. Abutment wall vertical cracks under beams 3W and 8W. Deformed bearing under beam 6W.	Abutment wall vertical cracks. Abutment wall cracking on SW face under backwall. Abutment wall vertical cracks under beam 4W.

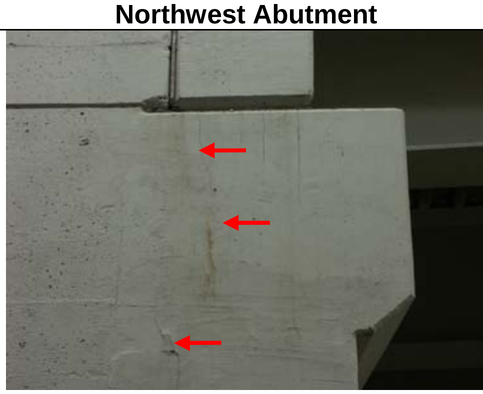
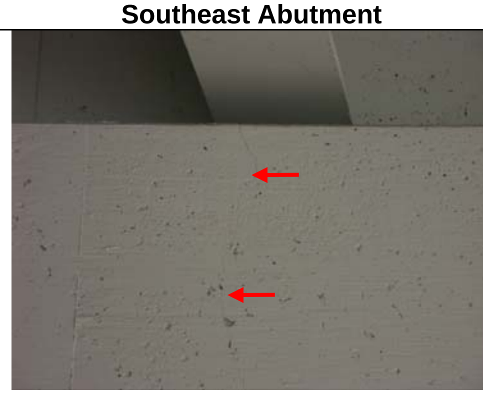
Northwest Abutment	Southeast Abutment
 Side crack on SW side underneath the backwall	 Vertical crack under beam 3W
 Vertical crack under beam 4W	 Deformation of bearing beam 6W

Photo D-3. Abutment Distress of S08-51027

Table D-4. Inspector Comments on Abutment Condition of B01 - 10042

Inspection Date	Inspector Comments--Abutment Conditions	
	Northwest Abutment	**Southeast Abutment**
10/6/1996	No inspector comments.	No inspector comments.
10/18/2000	Vertical cracks.	Vertical cracks.
7/30/2002	Vertical cracks.	Vertical cracks.
10/12/2004	Vertical cracks.	Vertical cracks.
11/4/2006	Abutment wall vertical cracks. Abutment wall vertical cracks under beams 1W, 2W, 3W, 4W, 6W, and 7W. Backwall cracking in the vicinity of beams 3W, 5W, and 6W.	Abutment wall vertical cracks. Abutment wall vertical cracks under beams 1W, 2W, 3W, 4W, 7W, and 8W. Diagonal backwall crack between beams 1W and 2W.

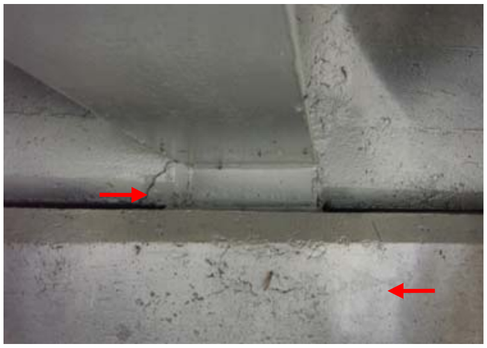
Northwest Abutment	Southeast Abutment
 Vertical crack under beam 2W	 Vertical crack under beam 1W
 Vertical crack under 3W and backwall cracking near beam end	 Diagonal backwall crack between beam 1W and 2W
 Backwall crack next to beam 5W	
 Horizontal crack at bearing beam 6W	

Photo D-4. Abutment Distress of B01 - 10042

Table D-5. Inspector Comments on Abutment Condition of S12-3-25042

Inspection Date	Inspector Comments--Abutment Conditions	
	Northeast Abutment	Southwest Abutment
10/24/1996	A few vertical cracks in abut wall.	A few vertical cracks in abut wall.
10/20/2000	A few vertical cracks in abut wall. Concrete appears sound.	A few vertical cracks in abut wall. Concrete appears sound.
10/3/2002	A few vertical cracks in abut wall. Concrete appears sound.	A few vertical cracks in abut wall. Concrete appears sound.
10/27/2004	A few vertical cracks in abut wall.	A few vertical cracks in abut wall.
11/5/2006	Vertical cracking on abutment wall. Vertical abutment wall cracking near bm 1W. Backwall concrete spall at bearing of beam 4W.	Vertical cracking on abutment wall. Vertical abutment wall cracking near beams 2W and 4W.

Northeast Abutment

Vertical crack under beam 1W

Spall at bearing under beam 4W

Southwest Abutment

Vertical crack under beam 2W

Photo D-5. Abutment Distress of S12-3-25042

Table D-6. Inspector Comments on Abutment Condition of S12-4-25042

Inspection Date	Inspector Comments--Abutment Conditions	
	Northeast Abutment	Southwest Abutment
10/24/1996	Vertical cracks in abut wall.	Vertical cracks in abut wall.
10/20/2000	Vertical cracks in abut wall. Concrete appears sound.	Vertical cracks in abut wall. Concrete appears sound.
10/7/2002	Vertical cracks in abut wall. Concrete appears sound.	Vertical cracks in abut wall. Concrete appears sound.
4/3/2004	Vertical cracks in abut wall. Concrete appears sound.	Vertical cracks in abut wall. Concrete appears sound.
11/5/2006	Vertical abutment wall cracking between beams. Vertical abutment wall cracking near beams 1W and 4W. Backwall cracking at bearing of beams 1W, 3W, and 4W.	Vertical abutment wall cracks between beams. Vertical abutment wall cracking near beams 1W and 2W. Beam end spalling near bearing of beam 1W. Horizontal backwall cracking near bearing of beams 2W, 3W, and 4W.

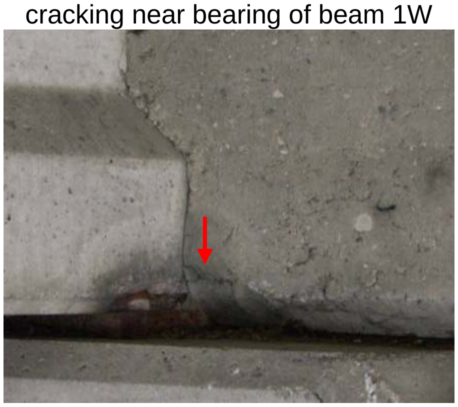
Northeast Abutment	Southwest Abutment
 Vertical abutment wall cracking and backwall cracking near bearing of beam 1W	 Vertical crack under beam 1W
 Horizontal backwall cracks at beam 3W	 Spalling at beam bearing 1W
 Vertical crack under beam 4W	 Horizontal backwall crack at beam bearing 2W
 Loss of bearing and backwall cracks at beam 4W	 Beam end spall at beam bearing 4W

Photo D-6. Abutment Distress of S12-4-25042

Table D-7. Inspector Comments on Abutment Condition of S12-7-25042

Inspection Date	Inspector Comments--Abutment Conditions	
	Northeast Abutment	Southwest Abutment
10/24/1996	A few cracks in abutment wall.	A few cracks in abutment wall.
10/20/2000	A few cracks in abutment wall. Concrete appears sound.	A few cracks in abutment wall. Concrete appears sound.
10/3/2002	A few cracks in abutment wall. Concrete appears sound. Will function as designed.	A few cracks in abutment wall. Concrete appears sound. Will function as designed.
10/28/2004	A few cracks in abutment wall.	A few cracks in abutment wall.
11/5/2006	Vertical abutment wall cracks between beams. Vertical abutment wall cracks near beams 1W and 2W. Beam end and backwall cracking in the vicinity of bearing of beam 3W.	Vertical abutment wall cracks between beams. Beam end spall in the vicinity of the bearing of beam 1W. Horizontal backwall cracking near bearing of beams 1W and 2W.

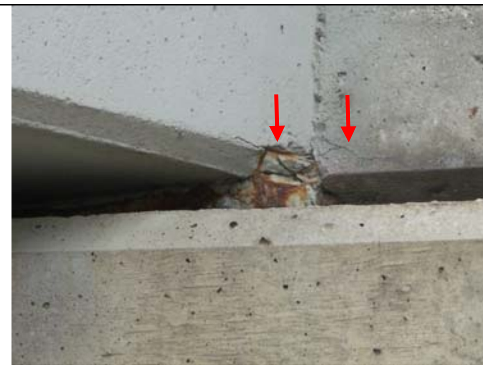
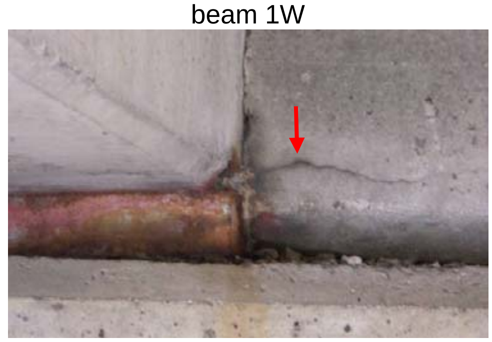
Northeast Abutment	Southwest Abutment
 Horizontal backwall and vertical abutment wall cracks at beam 1W	 Beam end spall and backwall cracks at bearing of beam 1W
 Vertical abutment wall crack under beam 2W	 Horizontal backwall crack at beam bearing 2W
 Crack at bearing under beam 3W	

Photo D-7. Abutment Distress of S12-7-25042

Table D-8. Inspector Comments on Abutment Condition of S12-8-25042

Inspection Date	Inspector Comments - Abutment Conditions	
	Northeast Abutment	Southwest Abutment
10/24/1996	Vertical cracks in abutment wall.	Vertical cracks in abutment wall.
10/20/2000	Several vertical cracks in abutment wall. Concrete appears sound.	Several vertical cracks in abutment wall. Concrete appears sound.
10/7/2002	Several vertical cracks in abutment wall. Concrete appears sound.	Several vertical cracks in abutment wall. Concrete appears sound.
10/28/2004	Tight vertical cracks in abutment wall.	Tight vertical cracks in abutment wall.
11/5/2006	Vertical abutment wall cracking between beams. Vertical abutment wall cracking near beam 2W. Beam end spalling near bearing of beam 2W. Beam and cracking near bearing of beam 3W.	Vertical abutment wall cracking between beams. Beam end cracking near bearing of beams 1W, 2W, and 3W. Backwall cracking near bearing of beam 3W.

Northeast Abutment	Southwest Abutment
 Vertical cracks under beam 2W	 Beam end crack near beam bearing 1W
 Beam end crack near beam bearing 3W	 Crack in beam 3W and horizontal backwall crack

Photo D-8. Abutment Distress of S12-8-25042

APPENDIX E

Table E-1. Moments and Axial Forces for Different Debonded Lengths

Debonded %		0.00%	2.50%	5.00%	7.50%
L_1 (HRRR)	M (ft-k)	-193	-83	-51	-34
	N (k)	0	0	0	0
L_2 (RHHR)	M (ft-k)	-63	-28	-19	-13
	N (k)	151	157	159	160
L_3 (RRHR)	M (ft-k)	-193	-83	-51	-34
	N (k)	0	0	0	0
TP_1 (HRRR)	M (ft-k)	142	80 61	53	
	N (k)	0	0 0 0		
TP_2 (RHHR)	M (ft-k)	74	50 44	42	
	N (k)	-79	-86 -84	-87	
TP_3 (RRHR)	M (ft-k)	142	80 61	53	
	N (k)	0	0 0 0		
TN_1 (HRRR)	M (ft-k)	-43	-24	-18	-16
	N (k)	0	0	0	0
TN_2 (RHHR)	M (ft-k)	-22	-15	-13	-13
	N (k)	24	26	25	26
TN_3 (RRHR)	M (ft-k)	-43	-24	-18	-16
	N (k)	0	0	0	0

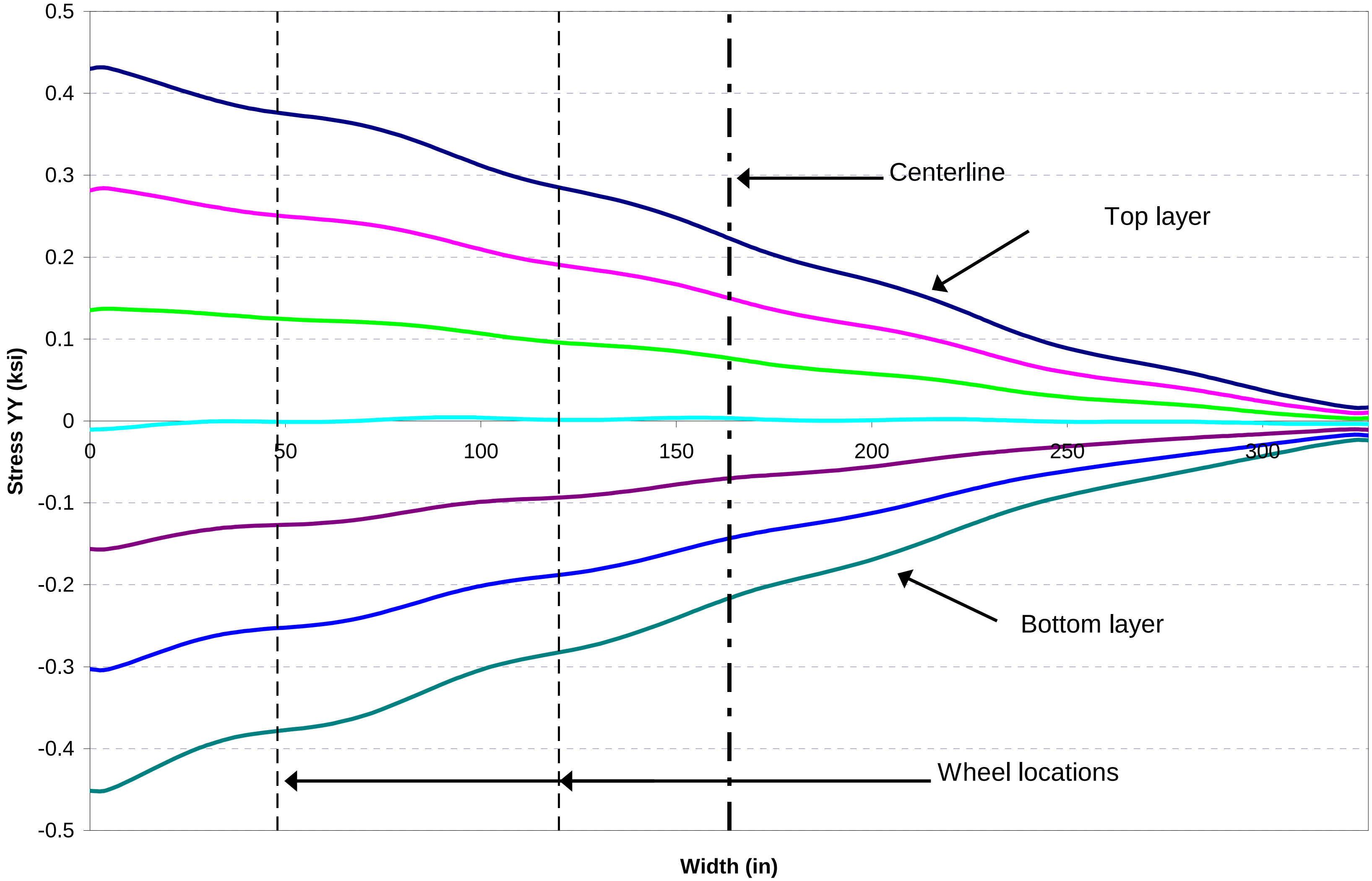


Figure E-1. Stresses YY distribution along the width for L_1 case for one lane straight full bridge

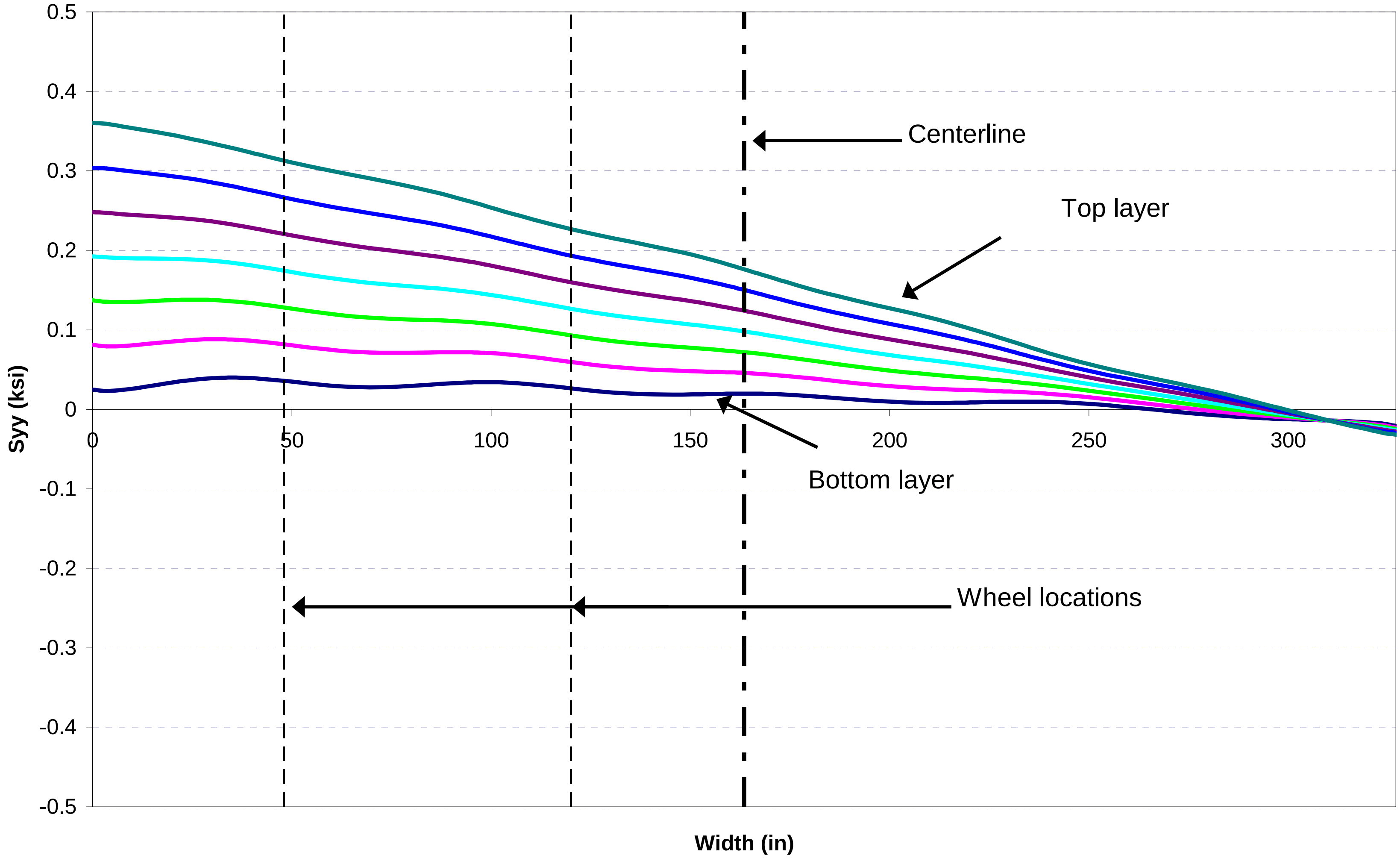


Figure E-2. Stresses YY distribution along the width for L_2 case for one lane straight full bridge

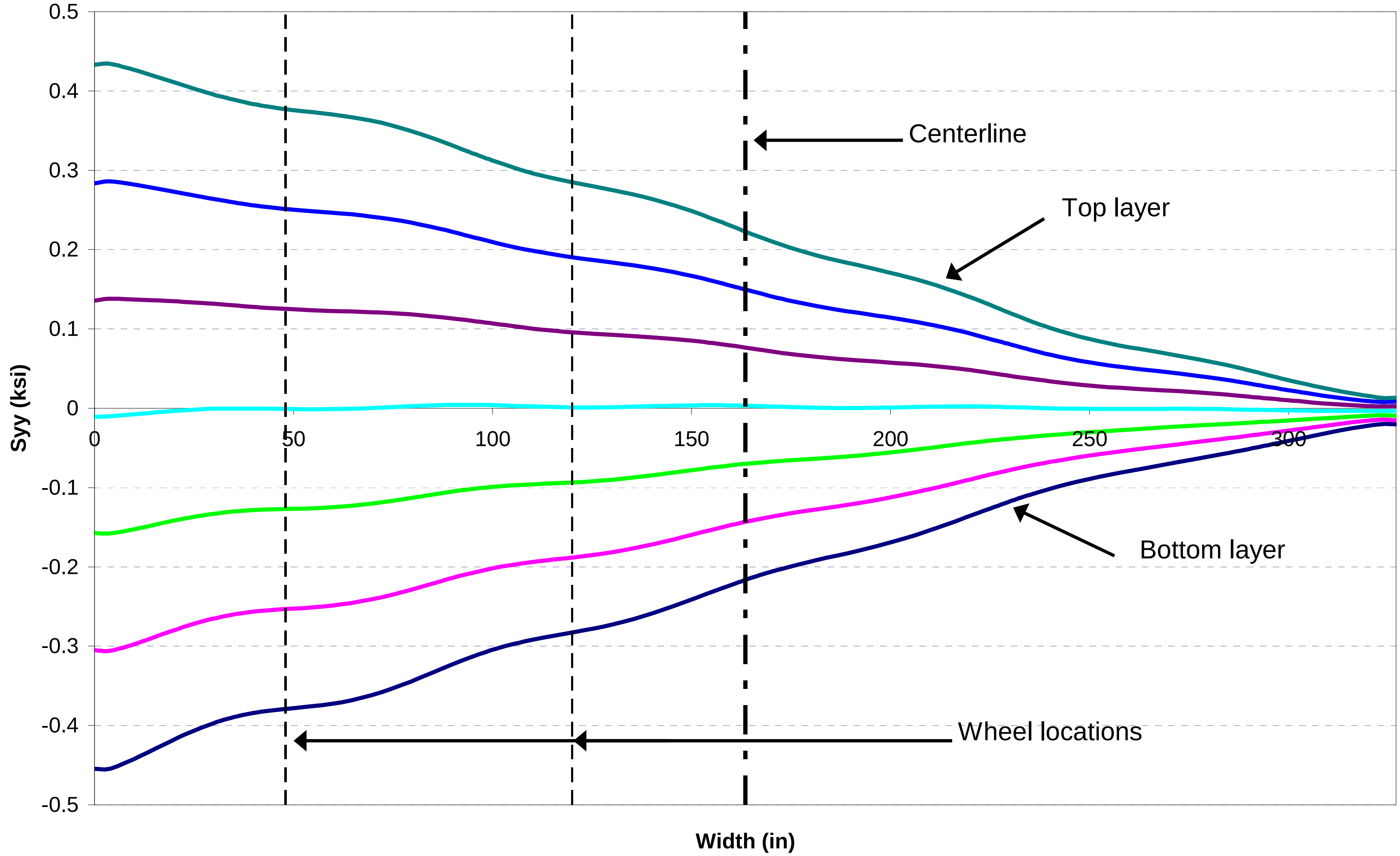


Figure E-3. Stresses YY distribution along the width for L_3 case for one lane straight full bridge

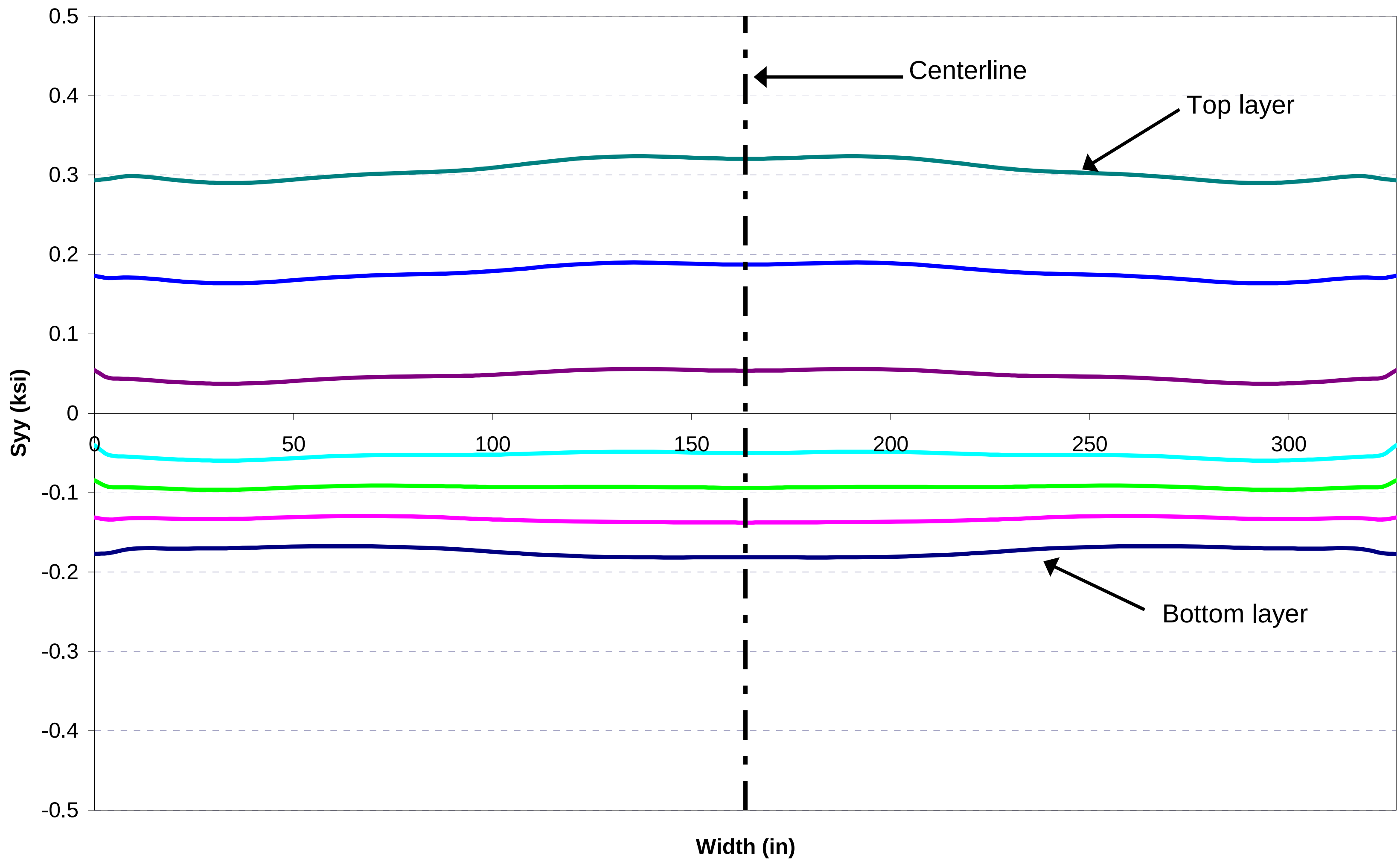


Figure E-4. Stresses YY distribution along the width for T_1 case for one lane straight full bridge

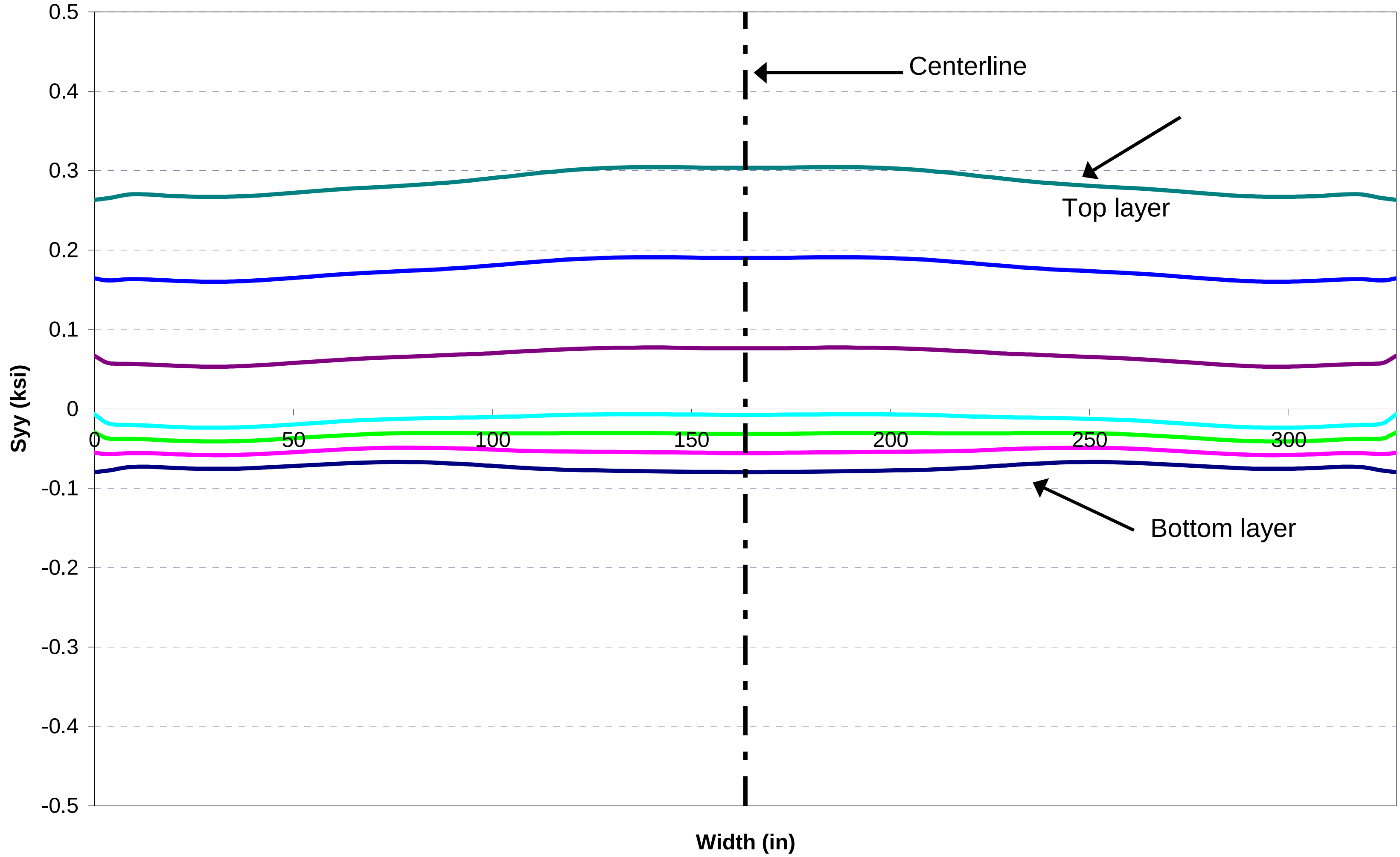


Figure E-5. Stresses YY distribution along the width for T_2 case for one lane straight full bridge

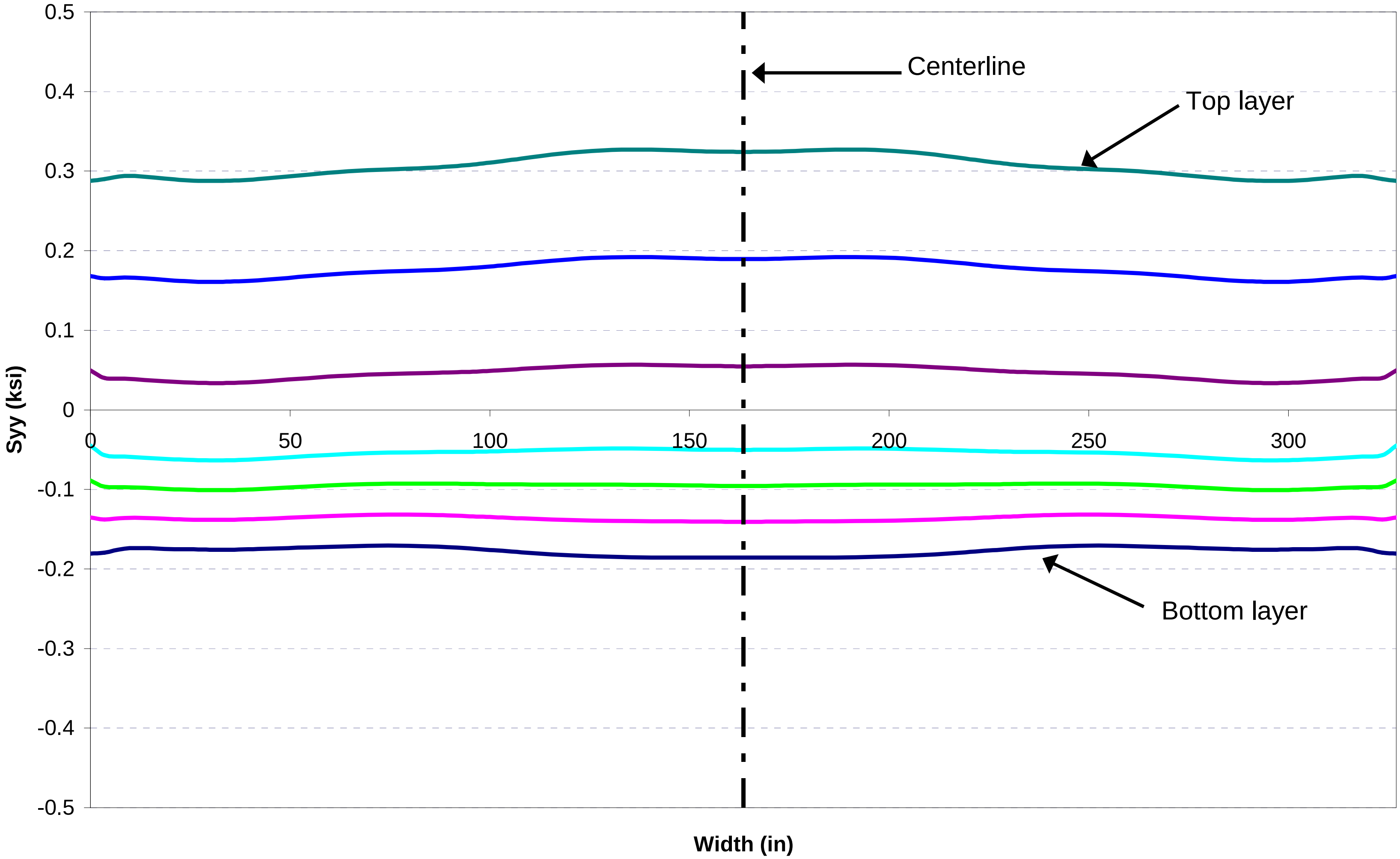


Figure E-6. Stresses YY distribution along the width for T_3 case for one lane straight full bridge

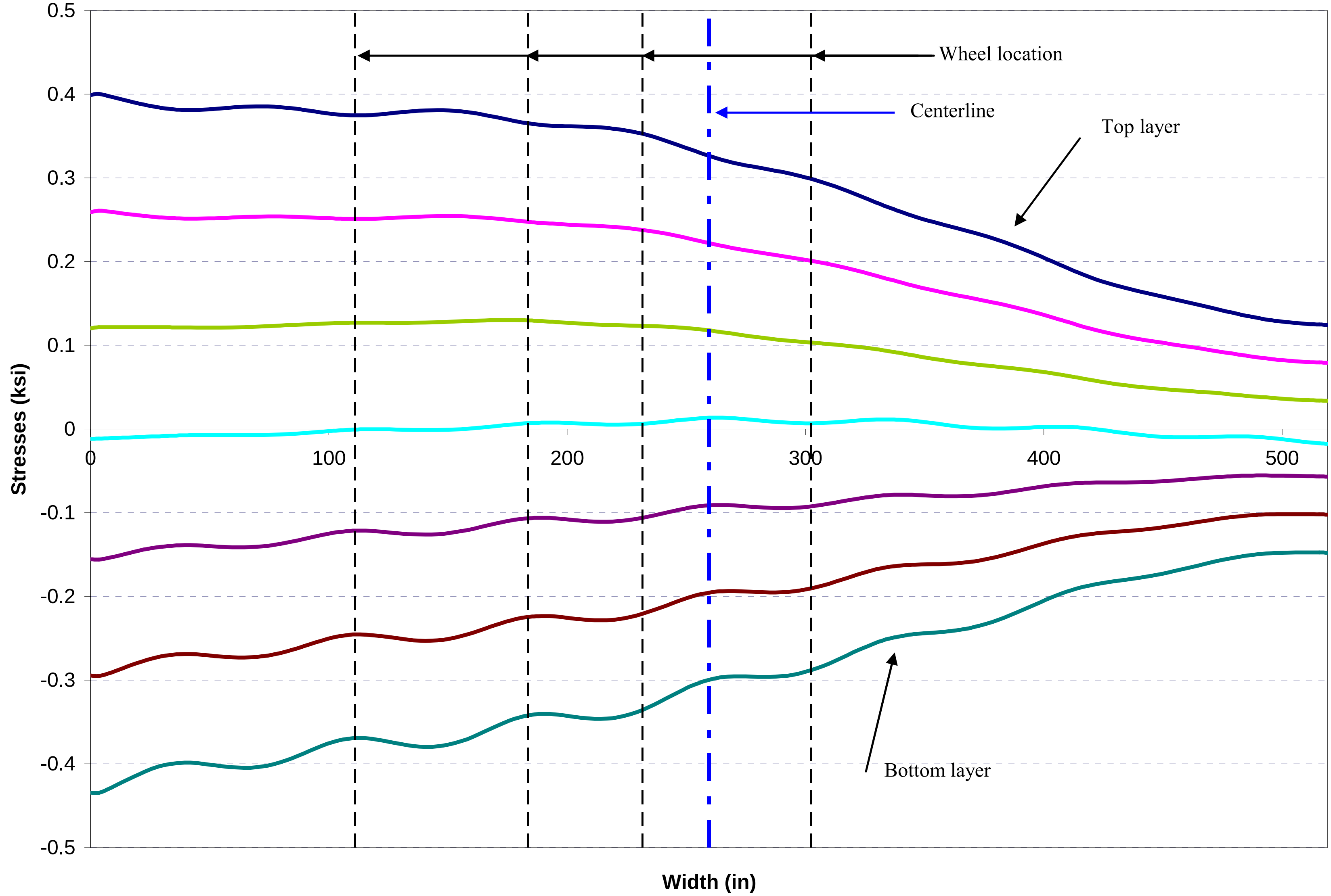


Figure E-7. Stresses YY distribution along the width for L_1 case for two lane straight full bridge

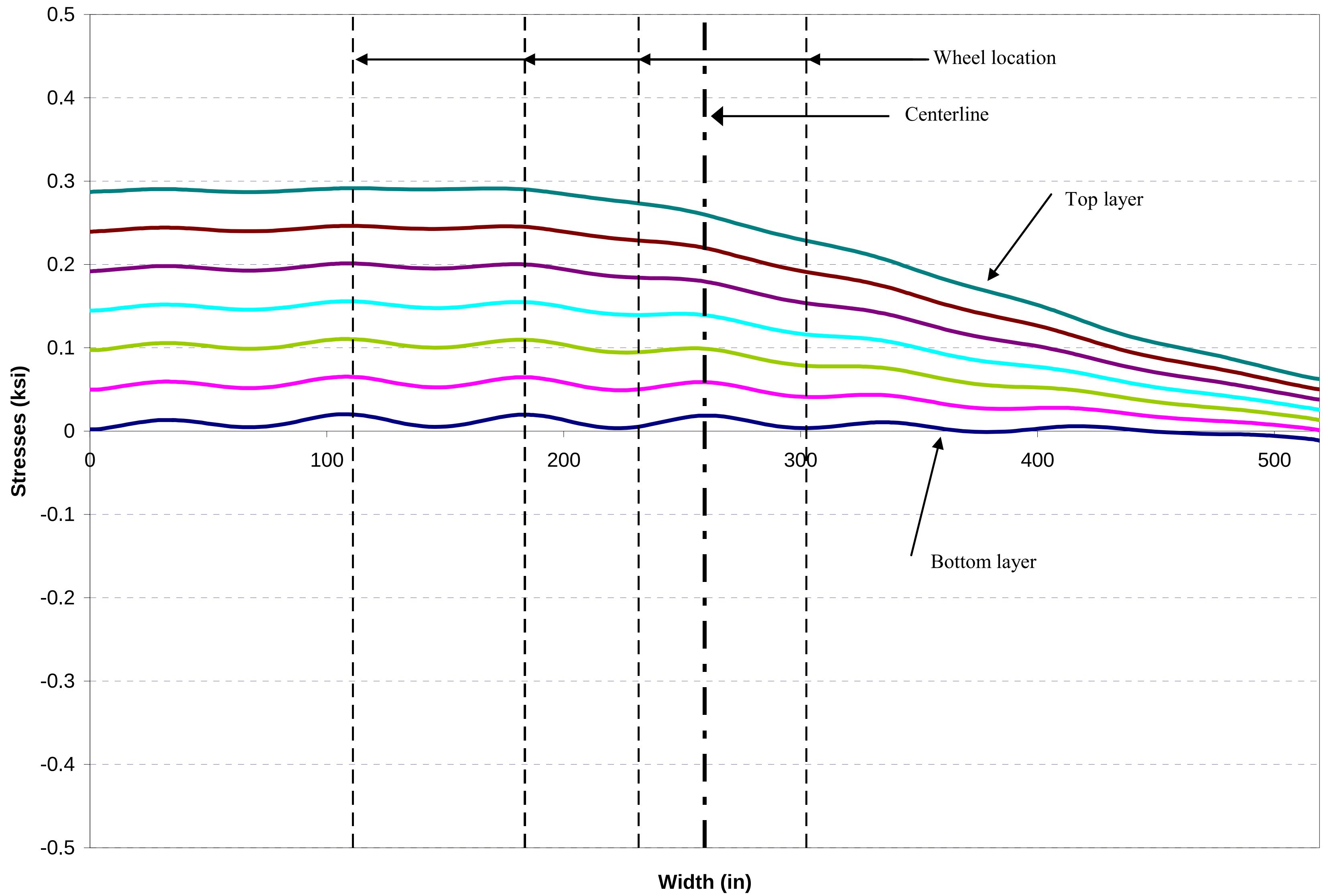


Figure E-8. Stresses YY distribution along the width for L_2 case for two lane straight full bridge

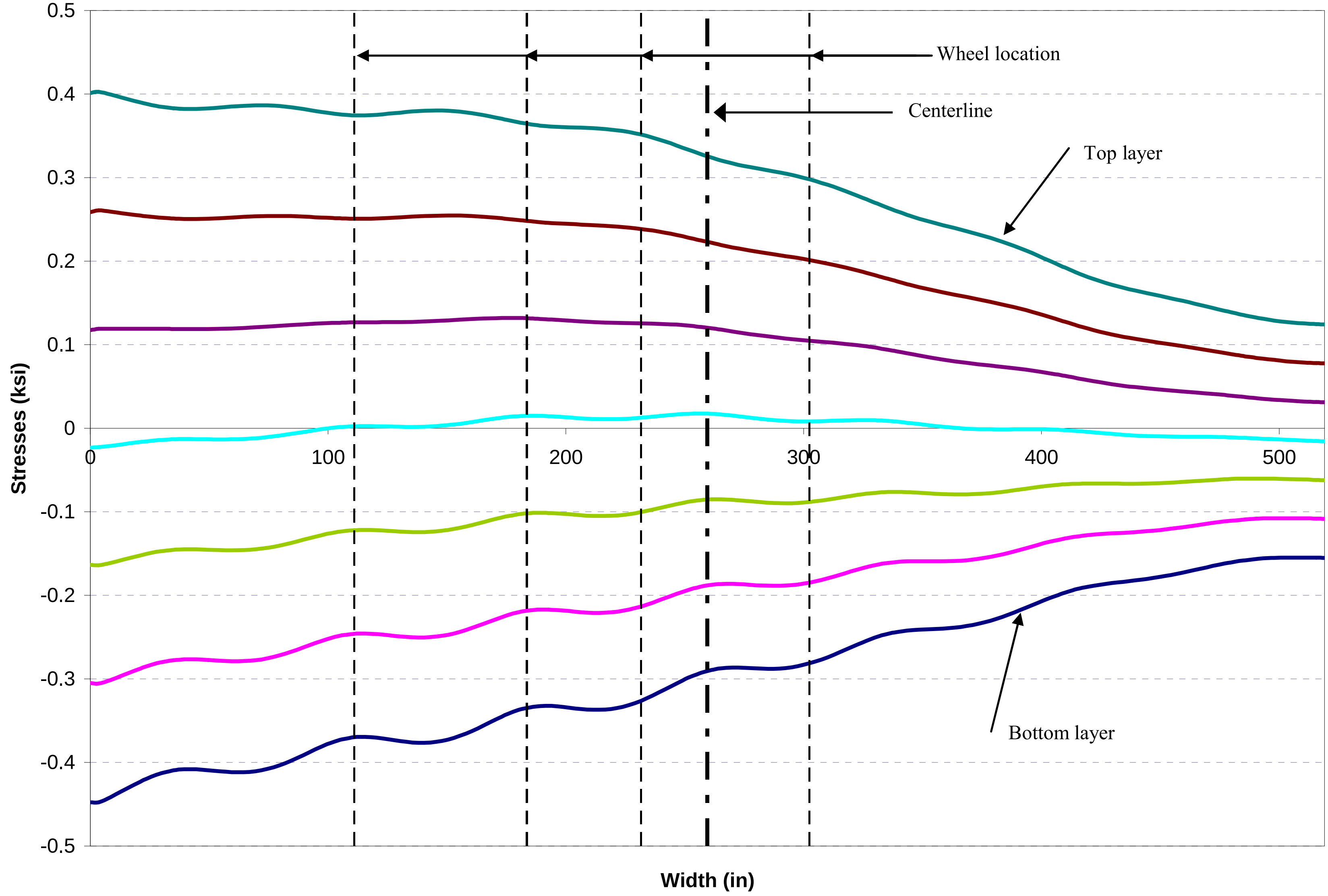


Figure E-9. Stresses YY distribution along the width for L_3 case for two lane straight full bridge

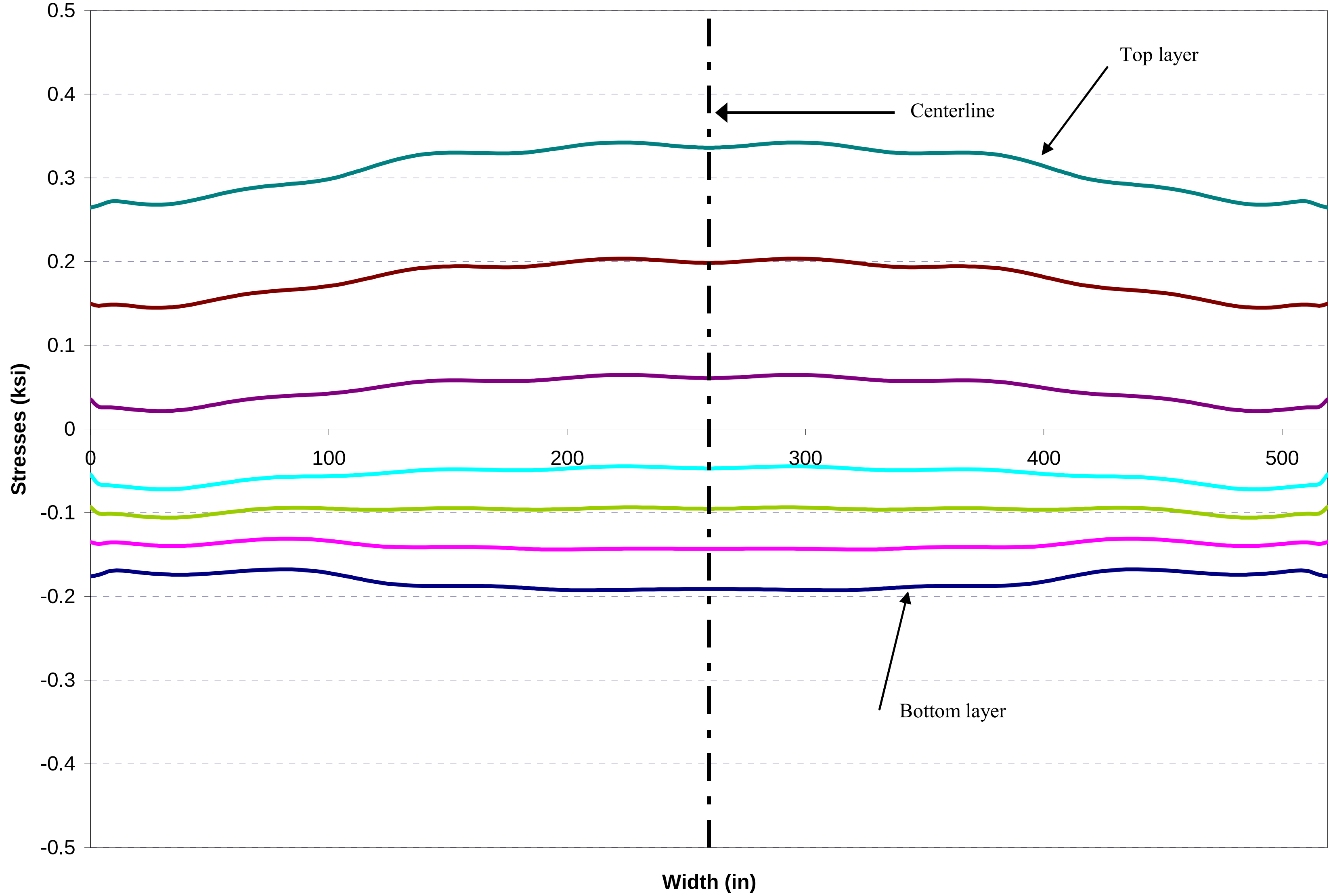


Figure E-10. Stresses YY distribution along the width for T_1 case for two lane straight full bridge

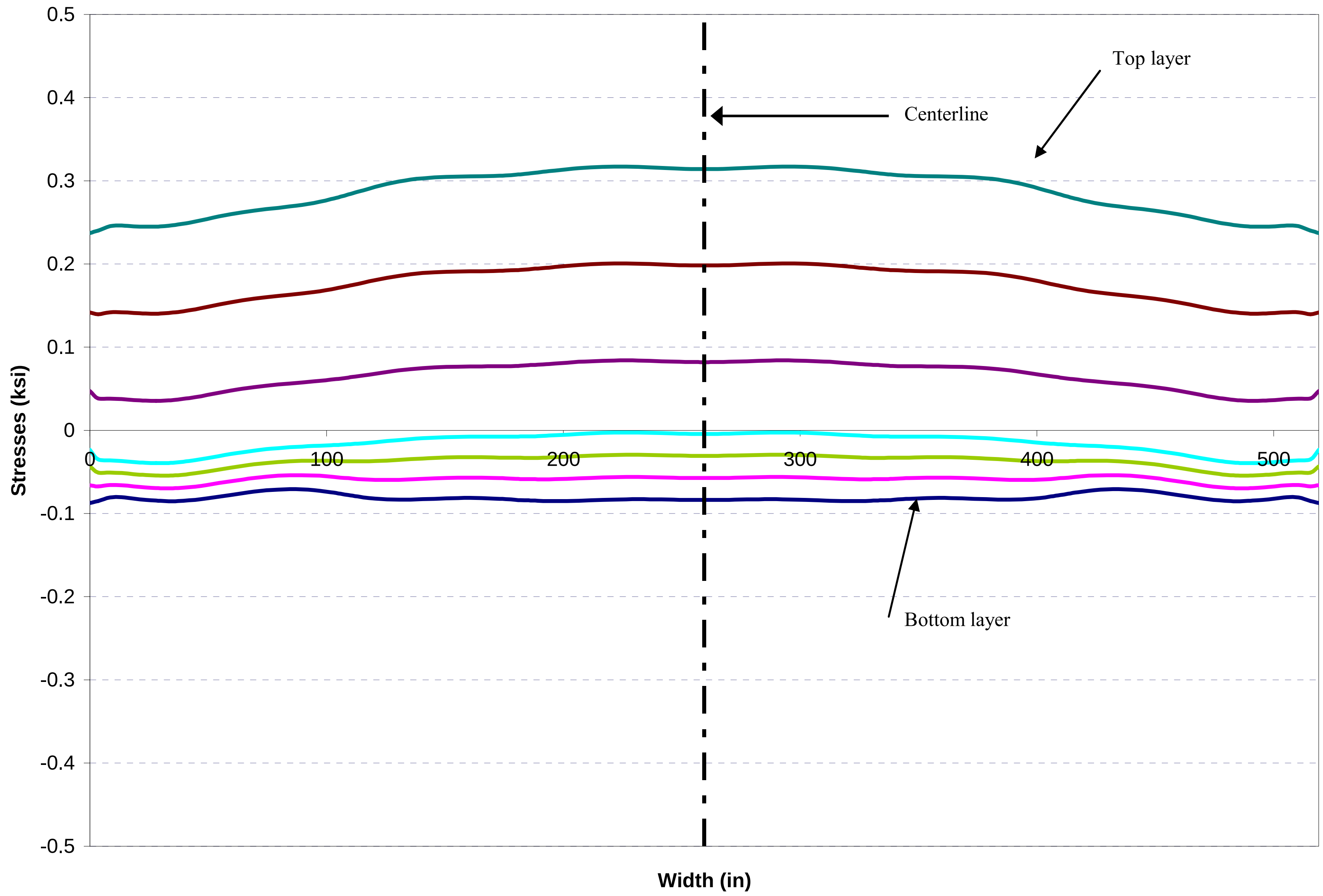


Figure E-11. Stresses YY distribution along the width for T_2 case for two lane straight full bridge

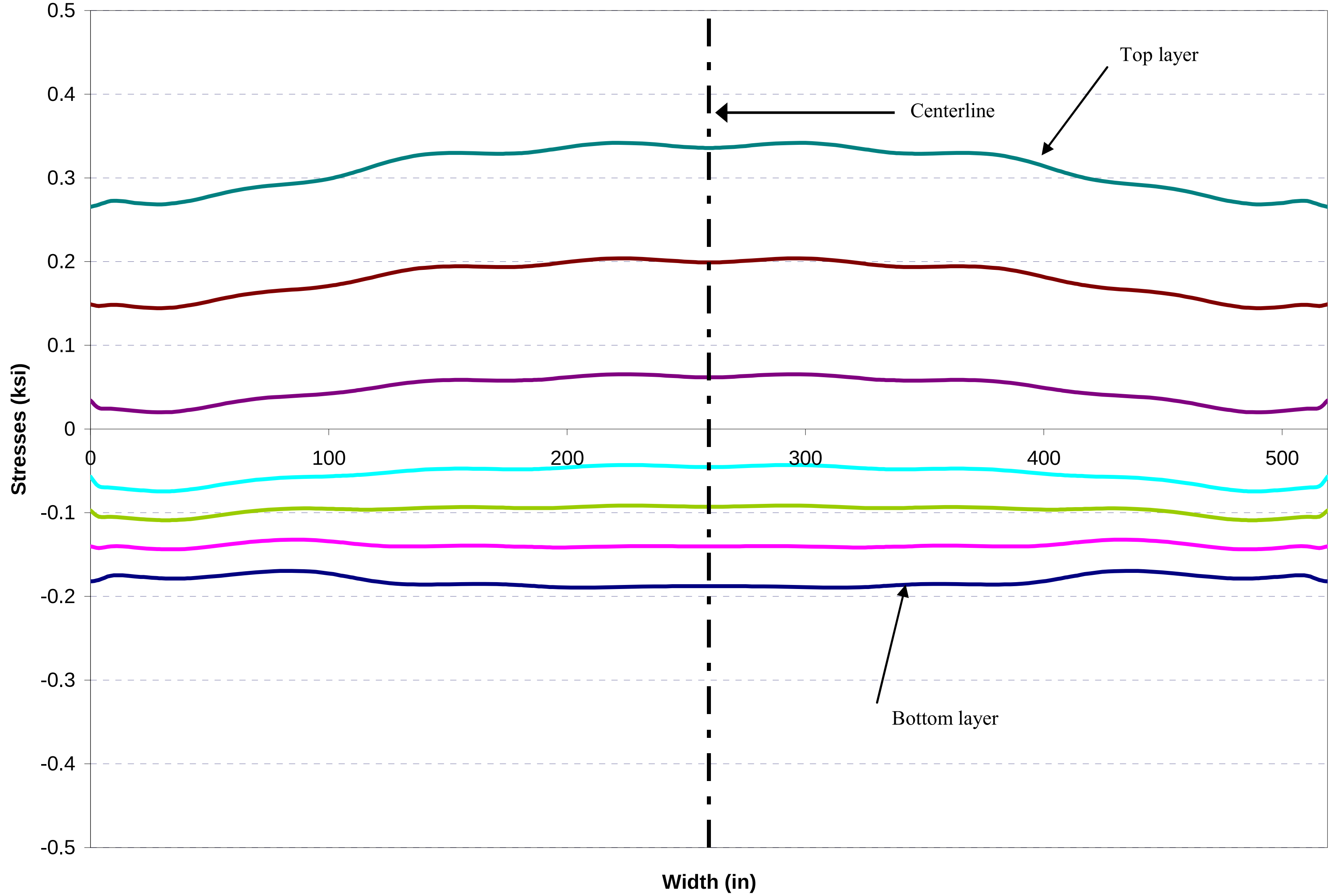


Figure E-12. Stresses YY distribution along the width for T_3 case for two lane straight full bridge

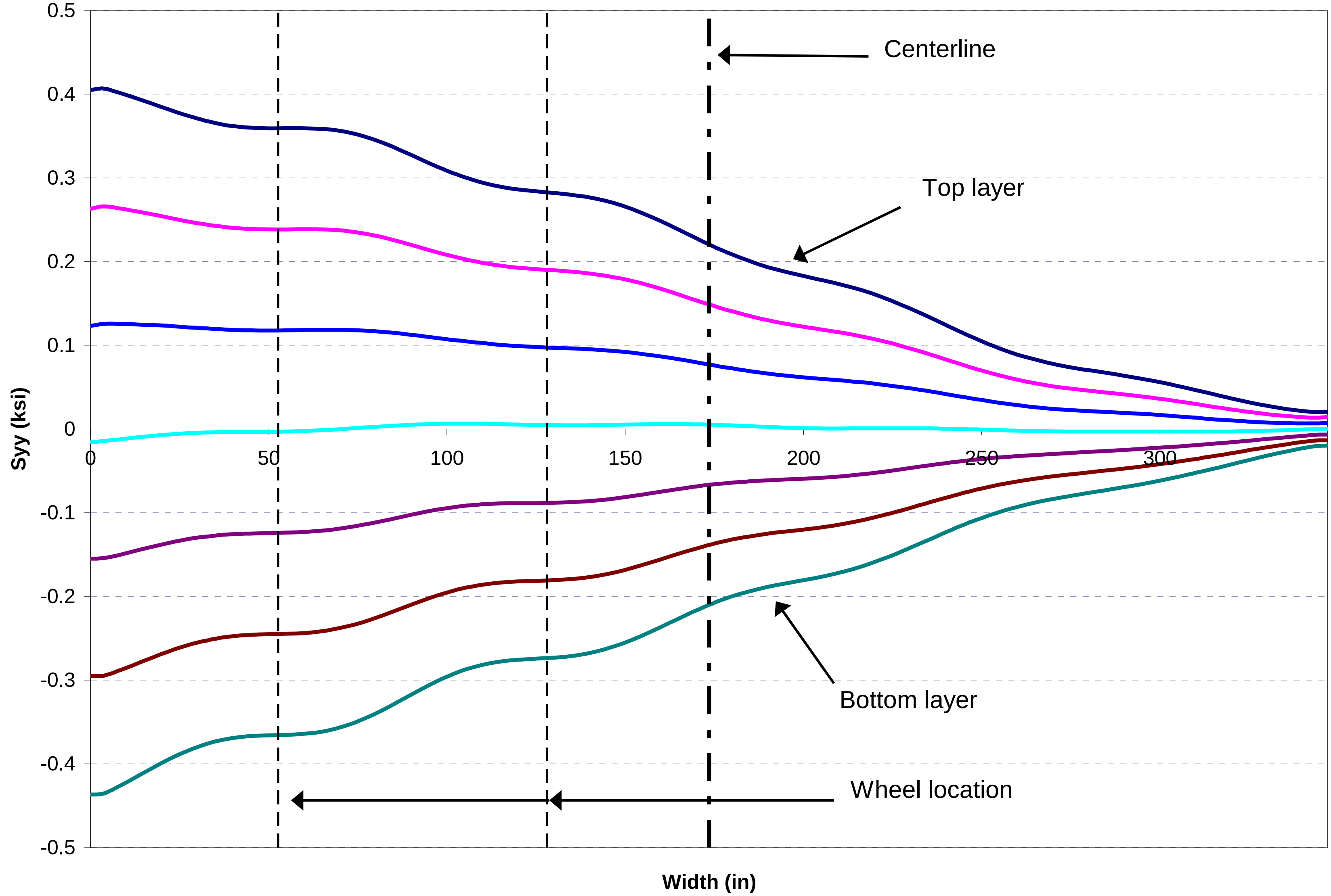


Figure E-13. Stresses YY distribution along the width for L_1 case for one lane 20^o skew full bridge (parallel to skew angle)

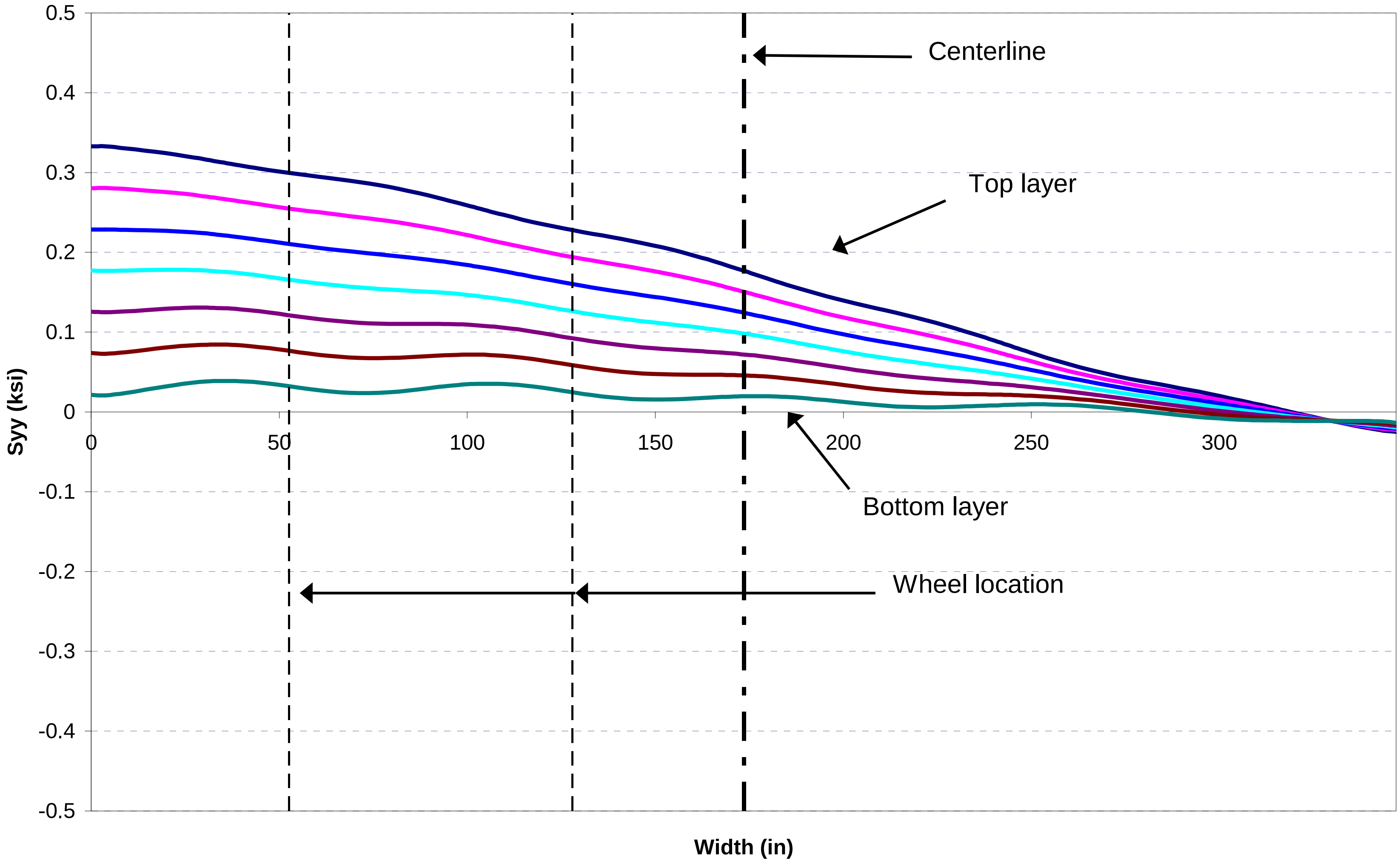


Figure E-14. Stresses YY distribution along the width for L_2 case for one lane 20^o skew full bridge (parallel to skew angle)

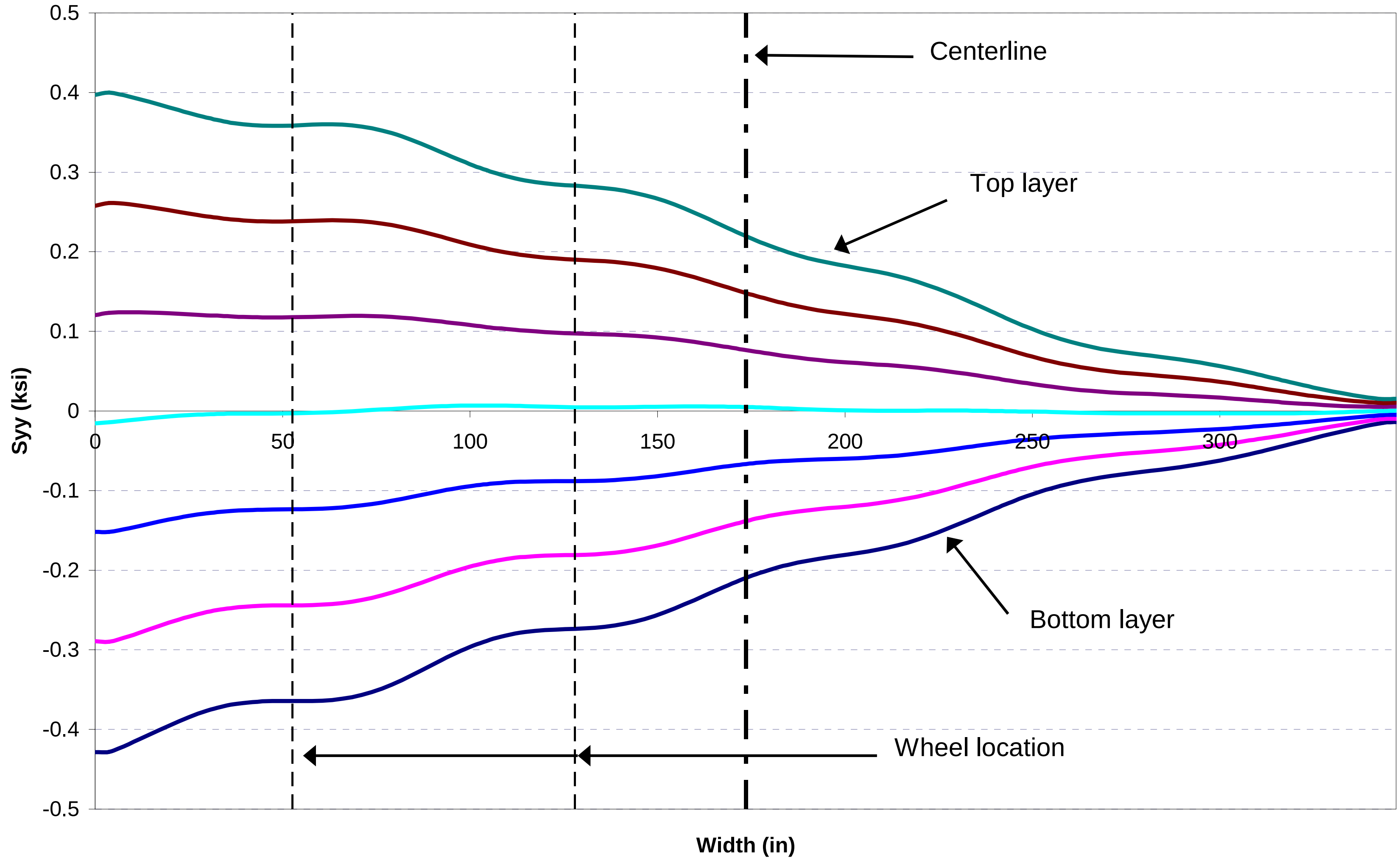


Figure E-15. Stresses YY distribution along the width for L_3 case for one lane 20^o skew full bridge (parallel to skew angle)

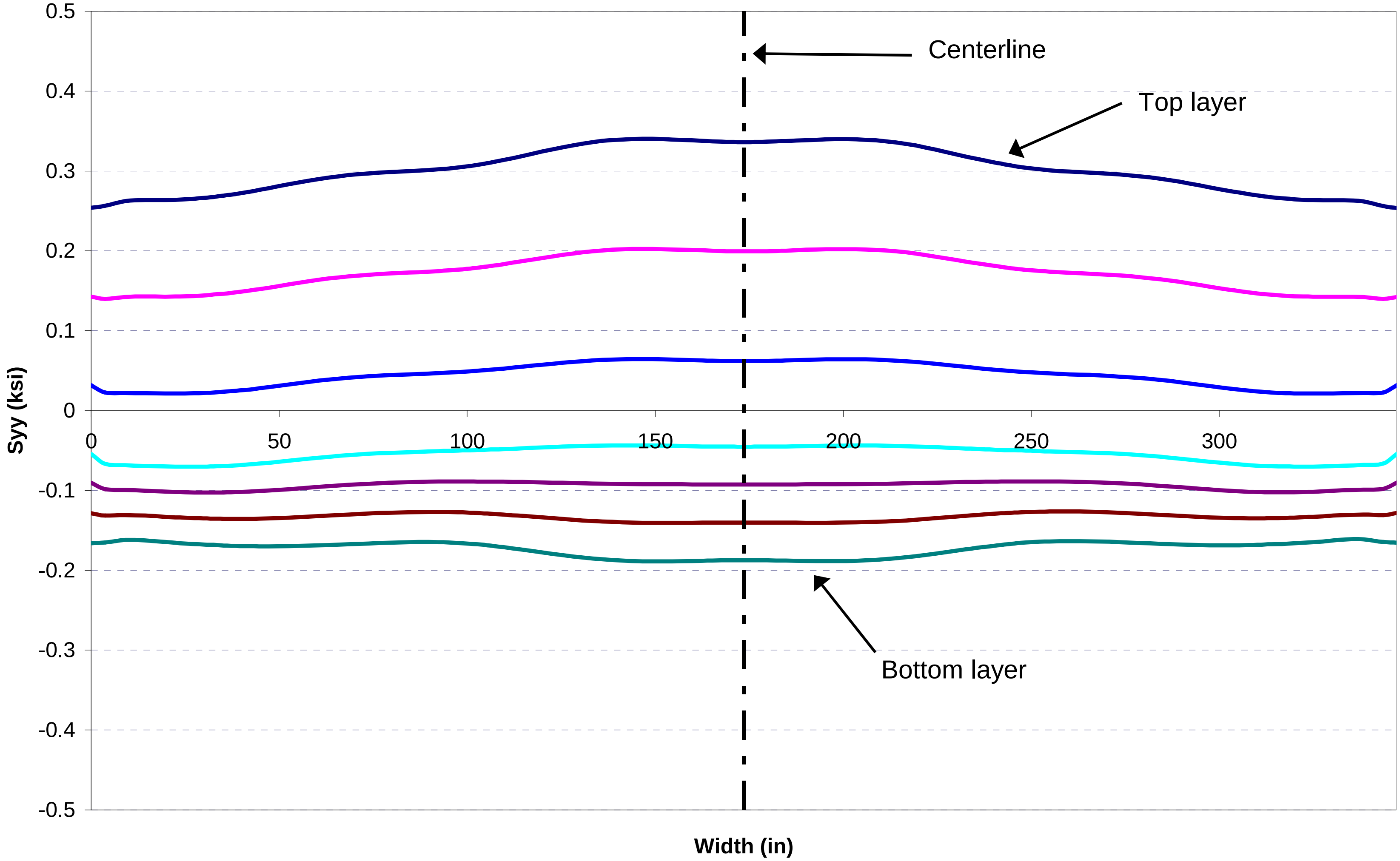


Figure E-16. Stresses YY distribution along the width for T_1 case for one lane 20^o skew full bridge (parallel to skew angle)

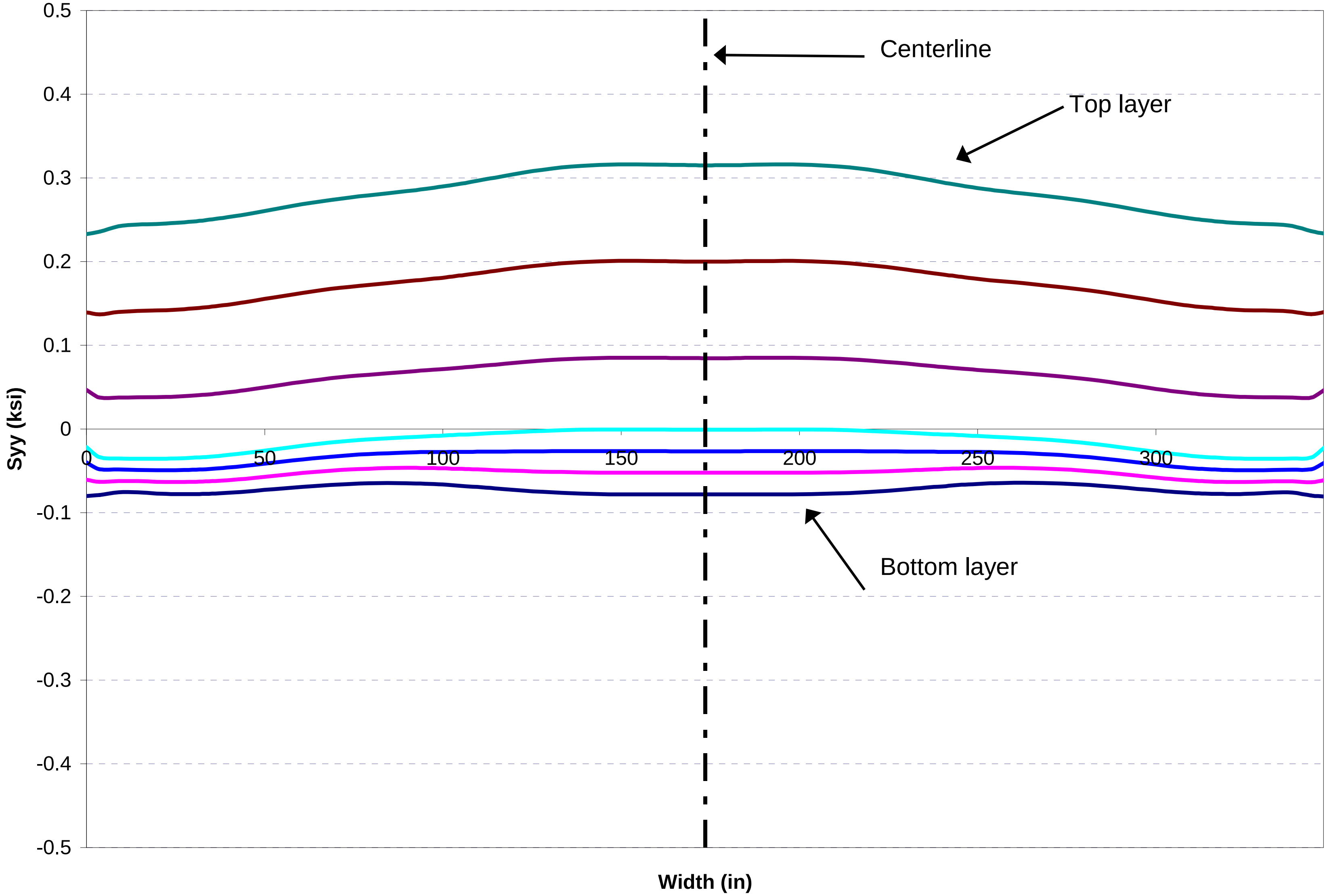


Figure E-17. Stresses YY distribution along the width for T_2 case for one lane 20^o skew full bridge (parallel to skew angle)

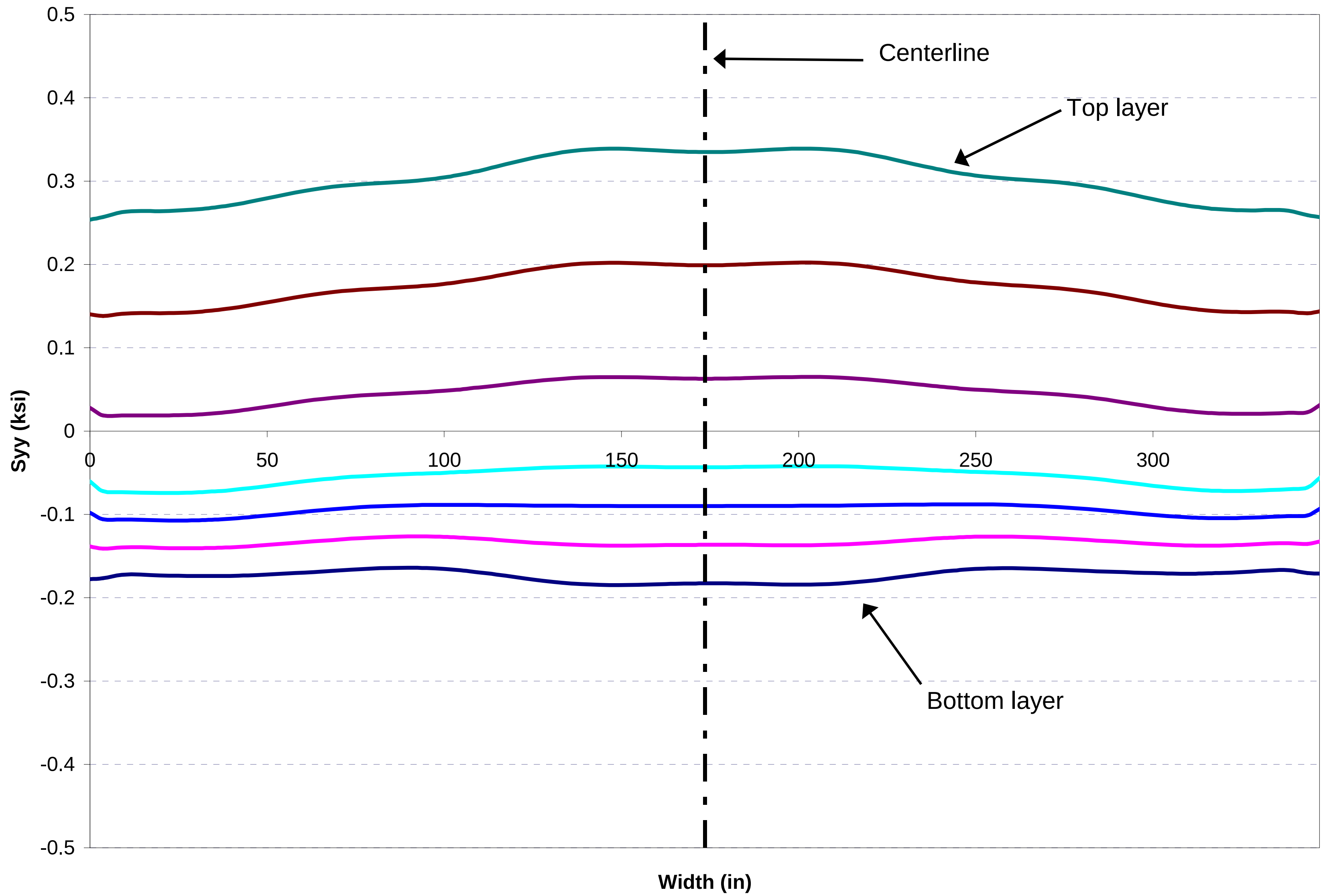


Figure E-18. Stresses YY distribution along the width for T_3 case for one lane 20^o skew full bridge (parallel to skew angle)

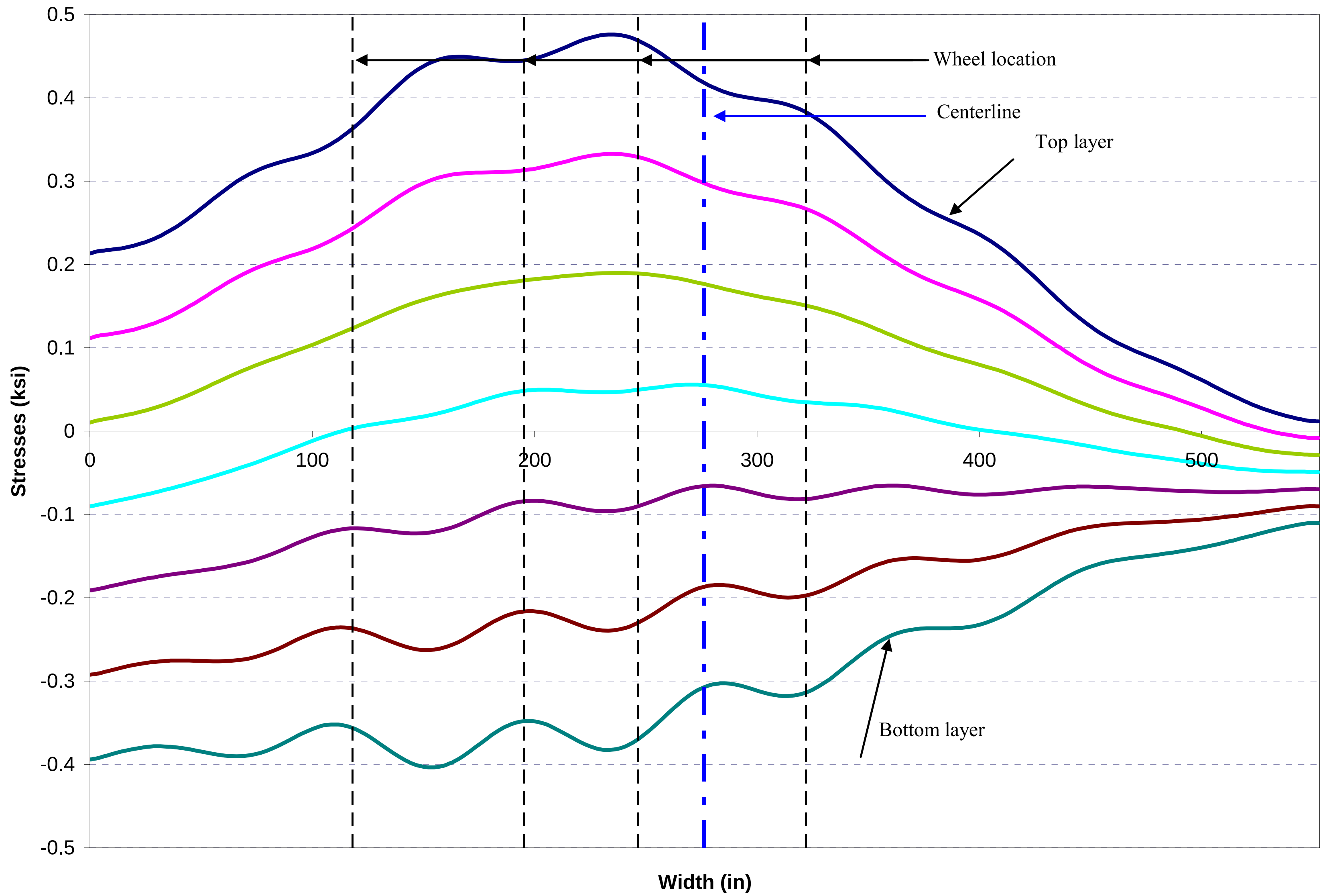


Figure E-19. Stresses YY distribution along the width for L_1 case for two lane 20^o skew full bridge (parallel to skew angle)

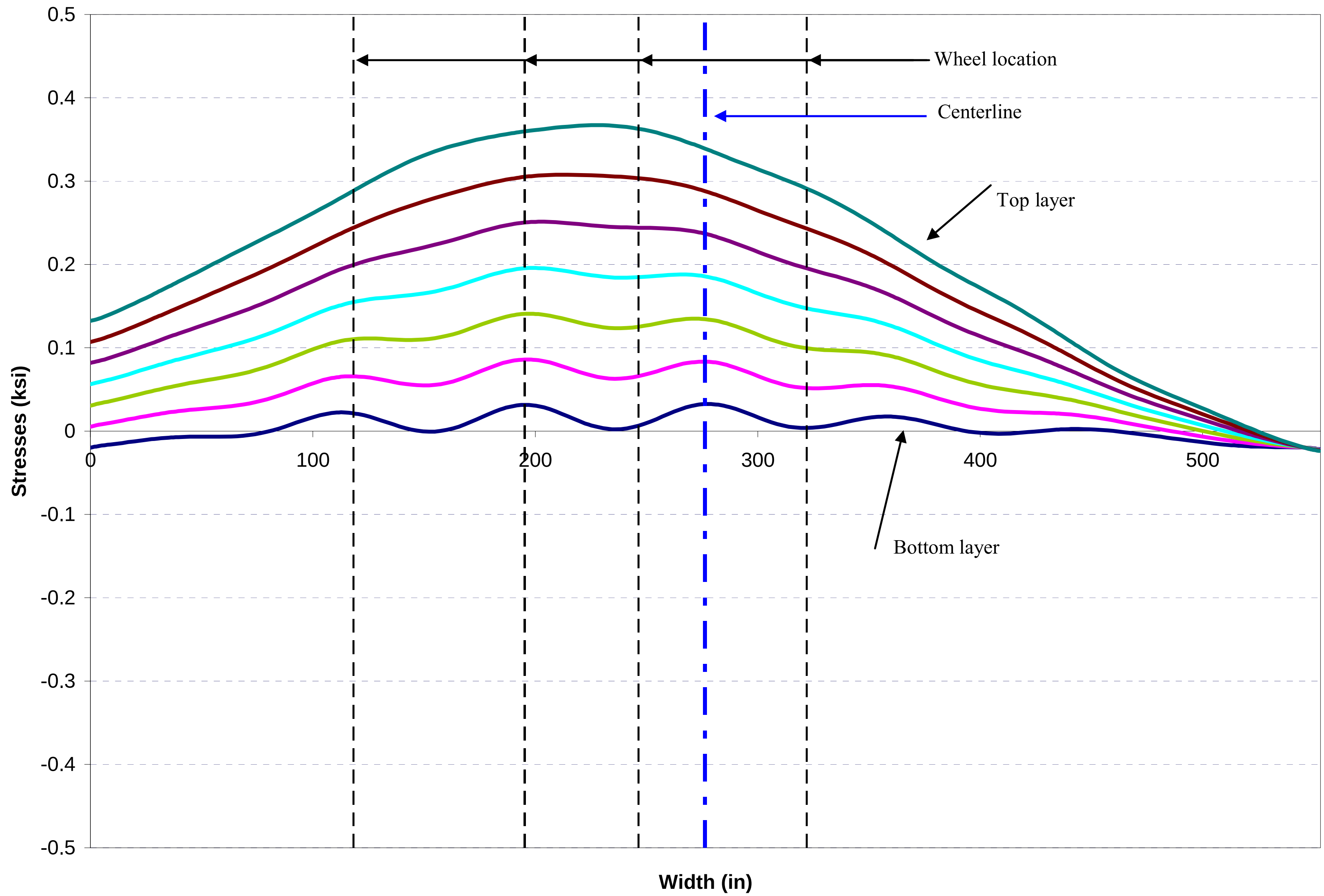


Figure E-20. Stresses YY distribution along the width for L_2 case for two lane 20^o skew full bridge (parallel to skew angle)

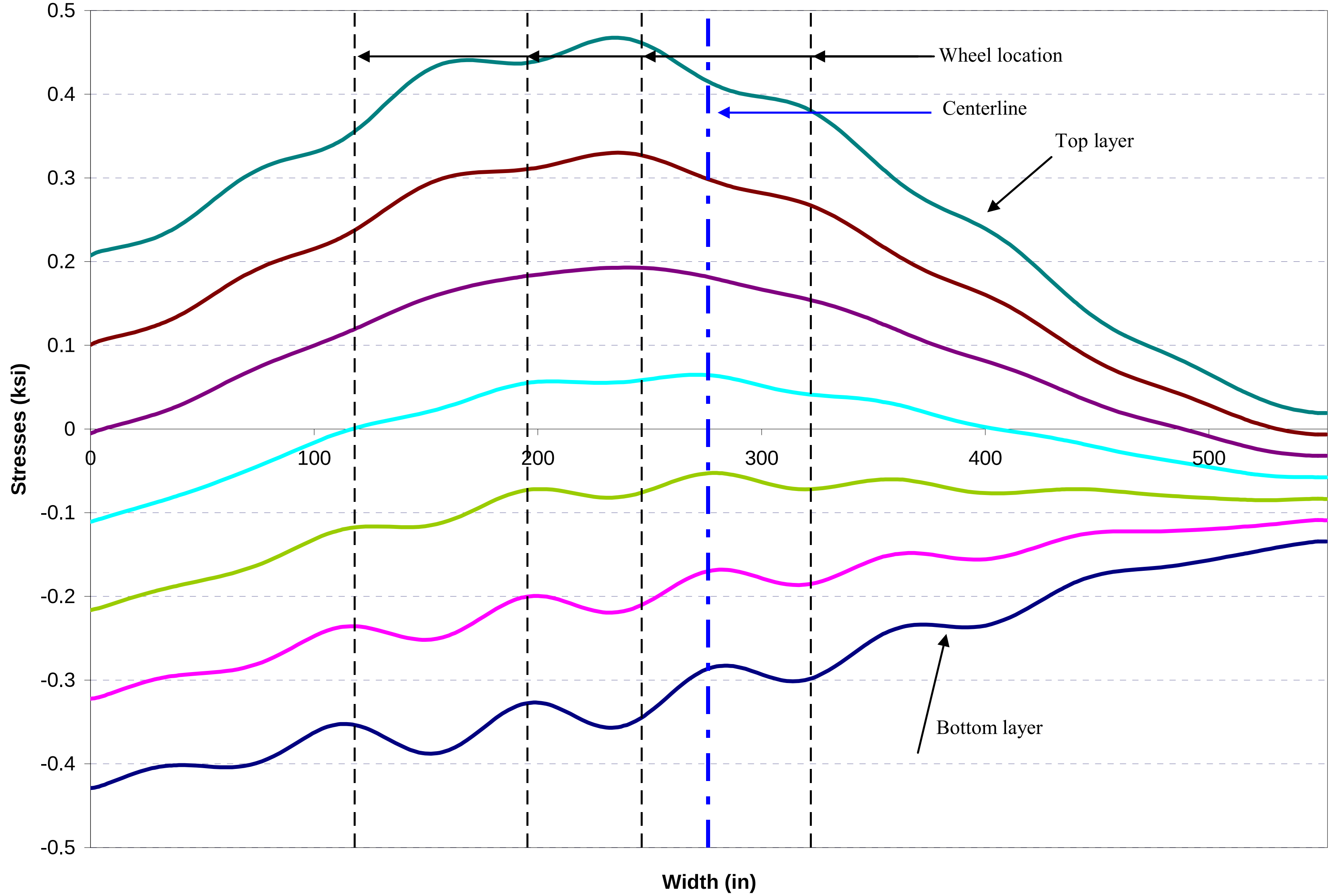


Figure E-21. Stresses YY distribution along the width for L_3 case for two lane 20° skew full bridge (parallel to skew angle)

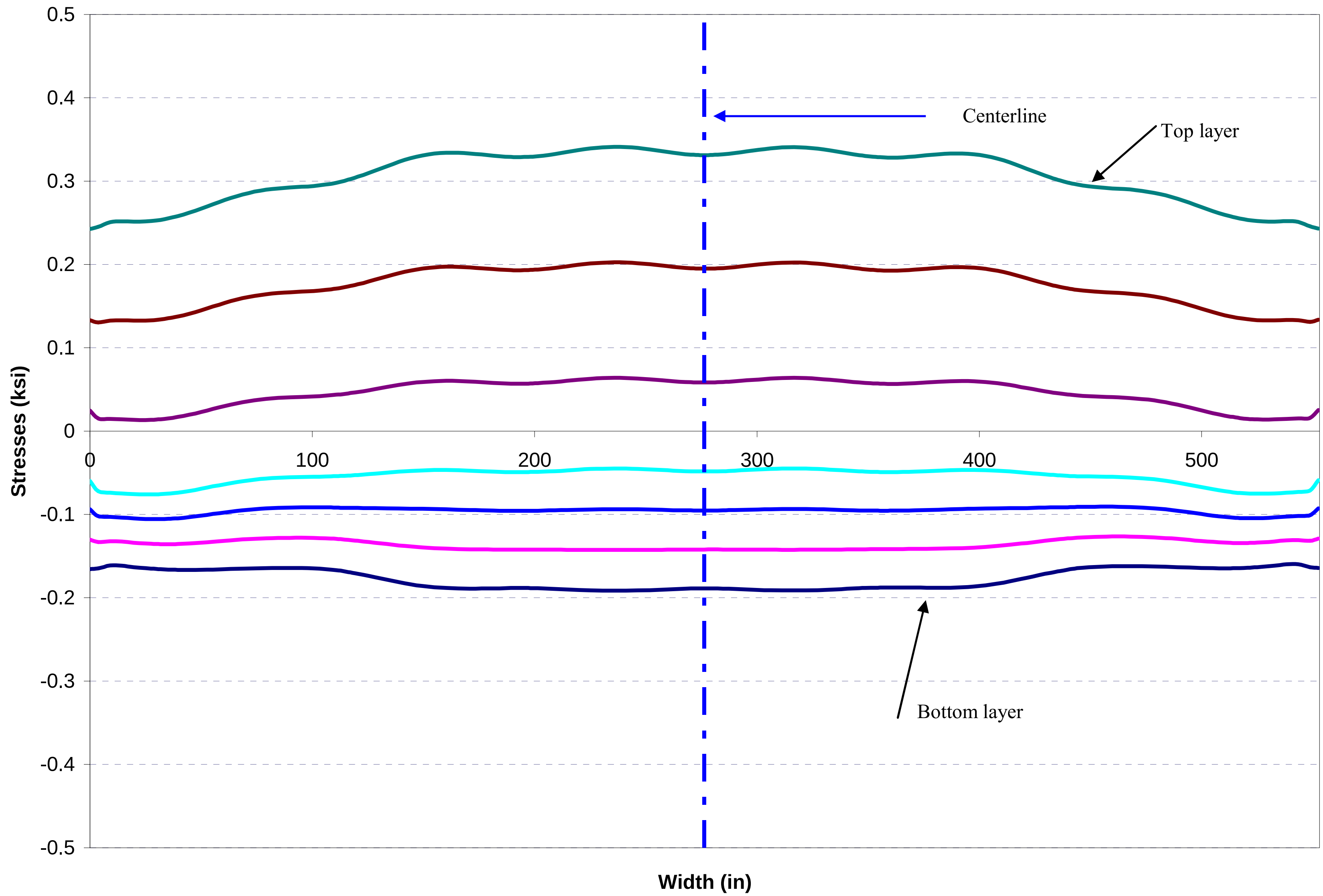


Figure E-22. Stresses YY distribution along the width for T_1 case for two lane 20^o skew full bridge (parallel to skew angle)

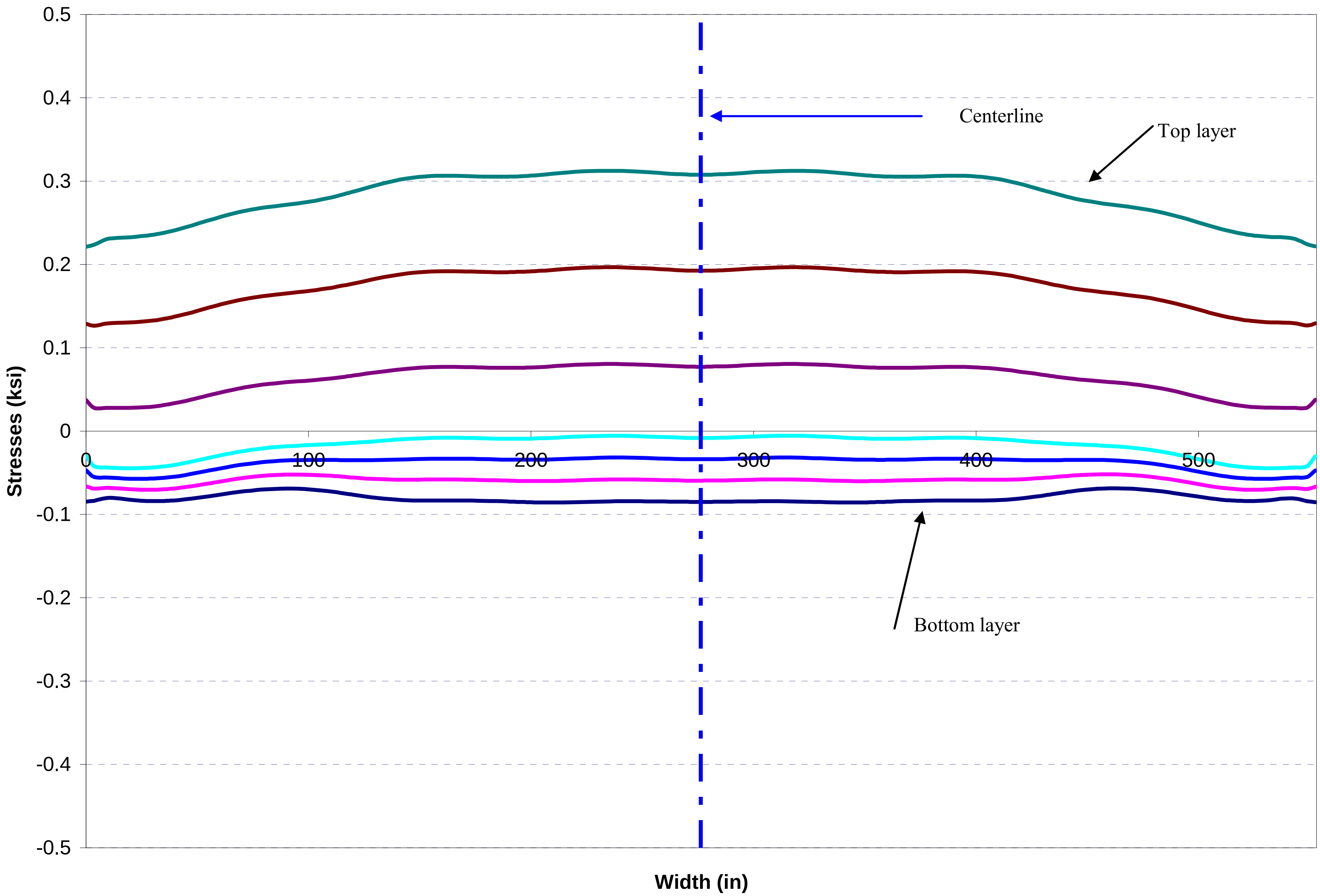


Figure E-23. Stresses YY distribution along the width for T_2 case for two lane 20^o skew full bridge (parallel to skew angle)

APPENDIX F

DESIGN PROCEDURE FOR LINK SLABS

DESIGN MOMENT

Design Procedure described in the appendix will follow the rationale developed by Caner and Zia (1998). AASHTO LRFD (2004) requires forces calculated from the combined effects of live and thermal loads for the service limit state design. Link slab design moments are calculated using the girder end rotations. HL-93 loading is used to calculate the girder end rotations under live load. Girder end rotations caused by temperature gradient are calculated using the procedure described by Saadeghvaziri and Hadidi (2002).

First step of the load analysis is to establish composite girder-deck cross-section with an effective width as per AASHTO LRFD (2004) Section 4.6.2.6, the composite moment of inertia, and define the modulus of elasticity for concrete.

Girder End Rotations due to Live Load

AASHTO LRFD (2004) procedures are followed:

Apply HL-93 loading [HS-20 truck with impact and distribution factor (LRFD section 3.6.2.1 and 4.6.2.2.2) + 0.64 kips/ft lane loading (LRFD 3.6.1.2.4)] on the simply supported spans to compute maximum girder end rotations (Note: the position of the truck is not necessarily coincident with positions that lead to either maximum midspan moment or deflection).

Girder End Rotations due to Temperature Gradient

The girder-deck composite cross-section is subjected to temperature gradient as described in AASHTO LRFD section 3.12.3 (Figure F-1).

Figure F-2 illustrates the strain compatibility of the sections, associated forces and moments developed in the sections and the temperature gradient profile along the depth of the cross-section.

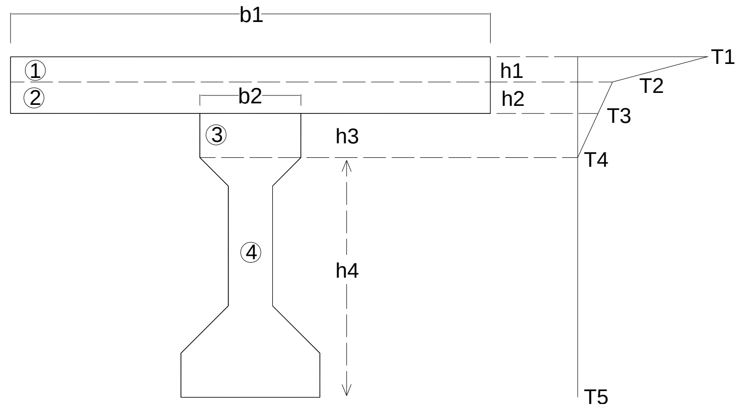


Figure F-1. Temperature profile along cross-section

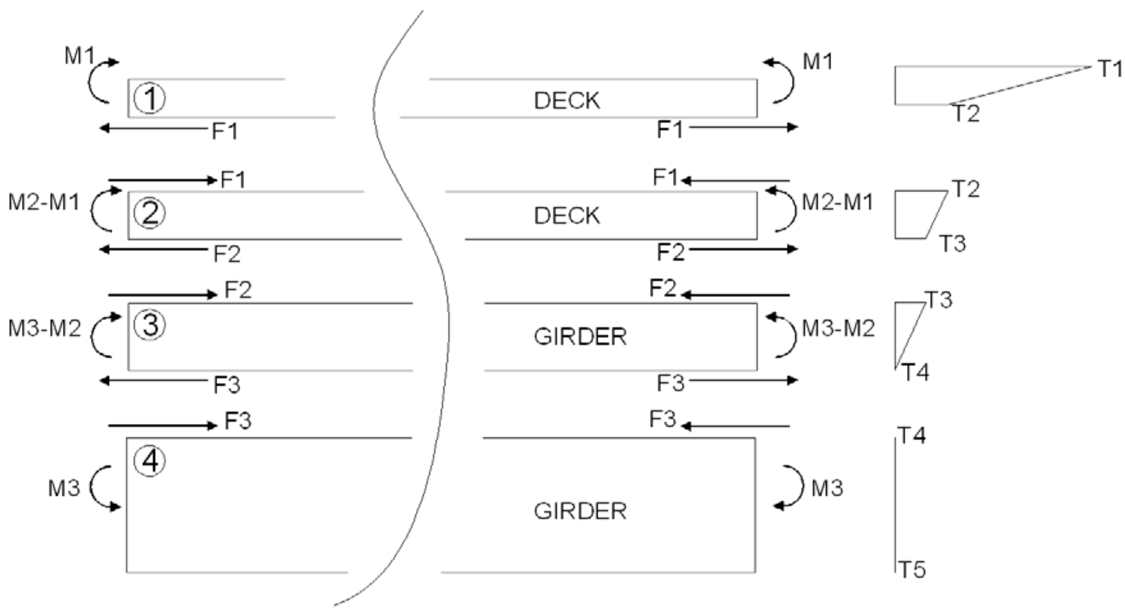


Figure F- 2. Compatibility forces and moments and temperature profile along cross-section height

Strain Compatibility

Using the relationship between forces and strains and using strain compatibility between sections 1 and 2, the following relationship is obtained;

$$\varepsilon_{Bottom1} = \alpha_1(T_2) + \frac{M_1}{E_1 S_{b1}} + \frac{F_1}{E_1 A_1} + \frac{F_1 d_{b1}}{E_1 S_{b1}} = \varepsilon_{Top2}$$

$$\varepsilon_{Top2} = \alpha_2(T_2) + \frac{M_2 - M_1}{E_2 S_{t2}} + \frac{F_2 - F_1}{E_2 A_2} + \frac{F_2 d_{b2} + F_1 d_{t2}}{E_2 S_{t2}} \qquad \text{(F-1)}$$

Repeating the formulation with using the strain compatibility between sections 2 and 3;

$$\varepsilon_{Bottom2} = \alpha_2(T_3) + \frac{M_2 - M_1}{E_2 S_{b2}} + \frac{F_2 - F_1}{E_2 A_2} + \frac{F_2 d_{b2} + F_1 d_{t2}}{E_2 S_{b2}} = \varepsilon_{Top3}$$

$$\varepsilon_{Top3} = \alpha_3(T_3) + \frac{M_3 - M_2}{E_3 S_{t3}} + \frac{F_3 - F_2}{E_3 A_3} + \frac{F_3 d_{b3} + F_2 d_{t3}}{E_3 S_{t3}} \qquad \text{(F-2)}$$

Repeating the formulation with using the strain compatibility between sections 3 and 4;

$$\varepsilon_{Bottom3} = \alpha_3(T_4) + \frac{M_3 - M_2}{E_3 S_{b3}} + \frac{F_3 - F_2}{E_3 A_3} + \frac{F_3 d_{b3} + F_2 d_{t3}}{E_3 S_{b3}} = \varepsilon_{Top4}$$

$$\varepsilon_{Top4} = \alpha_4(T_4) - \frac{M_3}{E_4 S_{t4}} - \frac{F_3}{E_4 A_4} + \frac{F_3 d_{t4}}{E_4 S_{t4}} \qquad \text{(F-3)}$$

Curvature Compatibility

Curvature compatibility between sections provides the following relationships:
Between sections 1 and 2;

$$\frac{1}{R_1} = \alpha_1\left(\frac{T_2 - T_1}{h_1}\right) + \frac{M_1}{E_1 I_1} + \frac{F_1 d_{b1}}{E_1 I_1} = \frac{1}{R_2}$$

$$\frac{1}{R_2} = \alpha_2\left(\frac{T_3 - T_2}{h_2}\right) + \frac{M_2 - M_1}{E_2 I_2} + \frac{F_1 d_{t2} + F_2 d_{b2}}{E_2 I_2} \qquad \text{(F-4)}$$

Between sections 2 and 3;

$$\frac{1}{R_2} = \alpha_2\left(\frac{T_3 - T_2}{h_2}\right) + \frac{M_2 - M_1}{E_2 I_2} + \frac{F_1 d_{t2} + F_2 d_{b2}}{E_2 I_2} = \frac{1}{R_3}$$

$$\frac{1}{R_3} = \alpha_3\left(\frac{T_4 - T_3}{h_3}\right) + \frac{M_3 - M_2}{E_3 I_3} + \frac{F_2 d_{t3} + F_3 d_{b3}}{E_3 I_3} \qquad \text{(F-5)}$$

Between sections 3 and 4;

$$\frac{1}{R_3} = \alpha_3\left(\frac{T_4 - T_3}{h_3}\right) + \frac{M_3 - M_2}{E_3 I_3} + \frac{F_2 d_{t3} + F_3 d_{b3}}{E_3 I_3} = \frac{1}{R_4}$$

$$\frac{1}{R_4} = \alpha_3\left(\frac{T_5 - T_4}{h_4}\right) - \frac{M_3}{E_4 I_4} + \frac{F_3 d_{t4}}{E_4 I_4} \qquad \text{(F-6)}$$

where

α_i : Coefficient of thermal expansion for Section i

T_i : Girder and deck temperature changes as given in Figure F-1 and Figure F- 2

F_i : Force resultant of stresses between section i and i+1

M_i : Moment resultant of stresses between section i and i+1

d_{bi} : Distance from centroid to bottom fiber of Section i

d_{ti} : Distance from centroid to top fiber of Section i

S_{bi} : Bottom section modulus for Section i

S_{ti} : Top section modulus for Section i

E_i : Modulus of elasticity of Section i

A_i : Cross-sectional area of Section i

I_i : Moment of inertia of Section i

Solving the above six equations F-1 through F-6 simultaneously for six unknowns (F_1, F_2, F_3, M_1, M_2, M_3), and plugging the forces back into F-4, F-5 and F-6 curvature values can be obtained.

End-slopes can be obtained from curvatures by integrating along the length as given below;

$$\frac{d\theta}{dx} = \frac{1}{R_1} = \frac{1}{R_2} = \frac{1}{R_3} = \frac{1}{R_4} = \frac{1}{R} \quad \theta(x) = \int \frac{1}{R} dx = \frac{x}{R} + C_1 \tag{F-7}$$

Eq. F-7 includes an integration constant C_1. For a simply supported span with length L, and since the slope at mid-span is zero due to symmetry under gradient loading, integration constant C_1 can be evaluated as;

$$\theta(\frac{L}{2}) = \frac{L}{2R} + C_1 = 0 \quad C_1 = -\frac{L}{2R} \tag{F-8}$$

Then, the slope equation and the slope at the beam end will be equal to;

$$\theta(x) = \frac{x}{R} - \frac{L}{2R} \quad \theta(L) = \frac{L}{R} - \frac{L}{2R} = \frac{L}{2R} \tag{F-9}$$

Link slab moment can be calculated from the girder end rotations under live and thermal gradient loads as given below:

$$M_a = \frac{2E_c I_d \theta}{L_L} \tag{F-10}$$

where,

I_d : Moment of inertia of the link slab

L_L : Length of the link slab (Debond zone length: sum of 5 % of each adjacent girder span + gap distance between beam ends)

DESIGN AXIAL FORCE

For a two-span system with RHHR supports, tensile force developed in the link slab would be equal to the horizontal reactions at the interior supports. The horizontal reaction is equal to the continuity moment divided by the distance between the centroid of deck and bearing location (Figure F-3).

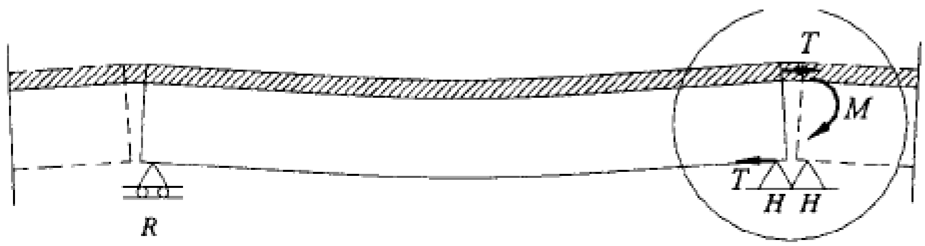


Figure F-3. Effect of RHHR type support condition on continuity (Okeil and El-Safty 2005)

Continuity Moment due to Live Load

Under live load, each span is loaded so as to create maximum negative moment at the interior support (Figure F-4) with composite cross-section properties. Any structural analysis program can be used to perform this analysis.

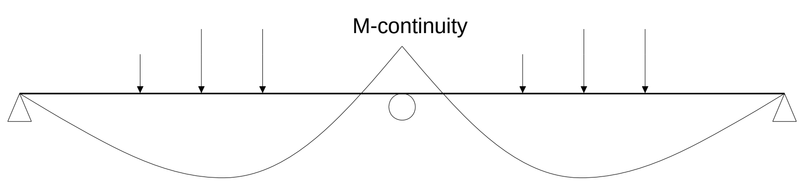


Figure F-4. Continuity moment at the interior support under live load

Continuity Moment due to Temperature Gradient

For a two-span-continuous system with constant cross-section in both spans, continuity moment $M_{continuity}$ can be calculated as;

$$M_{continuity} = \frac{(F_2 d_{tg} - M_3)(3E_{Composite} I_{Composite})}{2E_{Girder} I_{Girder}} \quad \text{(F-11)}$$

where

F_2 : Force resultant of stresses between section 2 and 3 calculated from six simultaneous equations

M_3 : Moment resultant of stresses between section 2 and 3 calculated from six simultaneous equations

d_{tg} : Distance from centroid to top fiber of girder

$E_{Composite}$: Modulus of elasticity of composite section

$I_{Composite}$: Moment of inertia of composite section

E_{Girder} : Modulus of elasticity of girder

I_{Girder} : Moment of inertia of girder

Once the continuity moment is found, tensile force in the link slab is;

$$T = \frac{M_{continuity}}{h} \tag{F-12}$$

where h is the distance between the centroid of deck and the top of the bearing.

Numerical Example

Cross-section properties of the girder and the composite section are given in Figure F- 5.

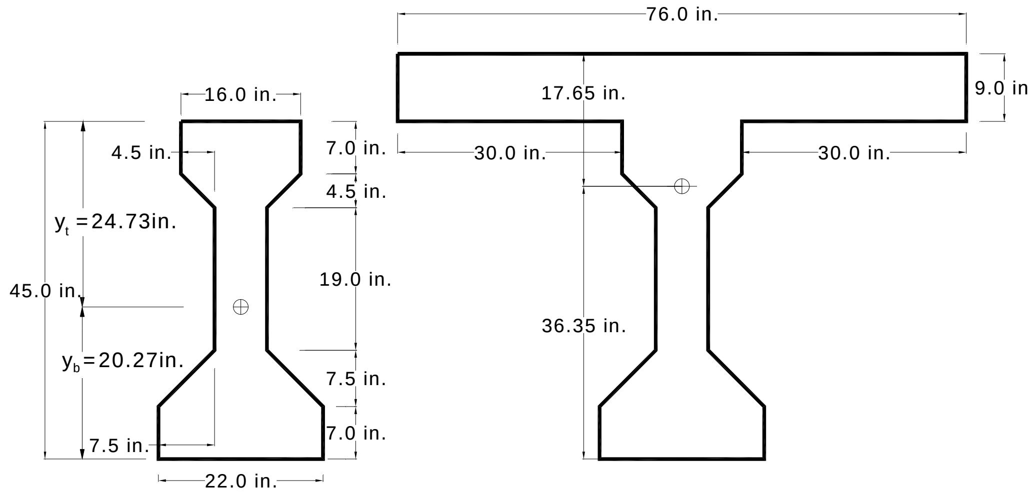


Figure F- 5. Girder and composite section geometric properties

The compressive strength of the girder and deck concrete (f_c') = 5000 psi.
Concrete modulus of elasticity (E_c) = 4031 ksi.
Reinforcement yield strength (f_y) = 60 ksi.
The deck overhang = 30 in. (on either side of the beam).
Composite inertia ($I_{composite}$) = 392,892 in^4.

DESIGN MOMENT

Live Load:

HL-93 (AASHTO LRFD 2004) loading is applied at a location to create maximum end rotation on the 69.5 ft span of the bridge. The impact factor is taken as 1.33 from Section 3.6.2.1 of AASHTO LRFD (2004). As per Section 3.6.1.3 AASHTO LRFD (2004), lane load of 0.64 k/ft is used in addition to the axle loads. Distribution factor is calculated as 0.571 assuming two or more lanes are loaded from the formulation in AASHTO LRFD (2004) Table 4.6.2.2.2b-1.

From the analysis maximum end rotation is calculated as 0.00154 radians when front axle is located 18.4 feet away from the end of the span.

Link slab length = 69.5×12×5%×2 + 1 in. gap = 84.4 inches
Gross moment of inertia of concrete link slab = 4617 in^4

Moment induced by live load:

$$M_a = \frac{2E_c I_d \theta}{L_L} = \frac{2\times 4031\times 4617\times 0.00154}{84.4\times 12} = -56.6 \quad ft.kips$$

for 76 in. wide effective section or

$$M_a = \frac{2E_c I_d \theta}{L_L} = \frac{2\times 4031\times 729\times 0.00154}{84.4\times 12\times(76/12)} = -8.9\, ft - \frac{kips}{ft}$$

Moment induced by temperature Gradient Loading:

b_1 = 76 in., b_2 = 16 in.

h_1 = 4 in., h_2 = 5 in., h_3 = 7 in., h_4 = 38 in.

$T_1 = 41^oF$, $T_2 = 11^oF$, $T_3 = 6.42^oF$, Positive temperature gradient (LRFD 3.12.3)
$T_4 = T_5 = 0$

E_c = 5000 ksi and α = 6 E-6 in./in./ ^{o}F for both deck and girder concrete

For section 4 of Figure F-1:

A_4 = 447.5 in^2, I_4 = 61889.67 in^4, d_{t4} = 23.09 in., S_{t4} = 2680 in^3

L_L = 84.4 in. and I_d = 4617 in^4 for the 76 in. × 9 in. deck cross-section

Solving simultaneous equations F-1 through F-6, internal forces and moments can be calculated as:

F_1 = -48.15 kips, F_2 = 32.90 kips, F_3 = 51.53 kips
M_1 = 195.31 in-kips, M_2 = 270.47 in-kips, M_3 = -3.61 in.kips

Then, the curvature can be calculated from any equation F-4 through F-6.

$$\frac{d\theta}{dx} = \frac{1}{R_1} = \frac{1}{R_2} = \frac{1}{R_3} = \frac{1}{R_4} = \frac{1}{R} = 3.857\times 10^{-6}$$

Then, the end rotation can be calculated with equation F-9.

$$\theta(L) = \frac{L}{R} - \frac{L}{2R} = \frac{L}{2R} = \frac{834}{2}\times 3.857\times 10^{-6} = 1.638\times 10^{-3} \quad rad$$

Finally, moment generated by positive temperature gradient load, according to equation F-10 is:

$$M_a = \frac{2E_c I_d \theta}{L_L} = \frac{2 \times 4031 \times 4617 \times 1.608 \times 10^{-3}}{84.4 \times 12} = 59.1 \quad ft.kips$$

for 76 in. wide effective section or

$$M_a = \frac{2E_{cI_d}\theta}{L_L} = \frac{2 \times 4031 \times 729 \times 1.608 \times 10^{-3}}{84.4 \times 12 \times (76/12)} = 9.4\, ft - kips/ft$$

Moment caused by negative thermal gradient will be -0.3 times the positive gradient loading.

$M_a = 59.1 \times -0.3 = -17.7 \quad ft.kips$ for 76 in. wide effective section or

$M_a = 9.4 \times -0.3 = -2.8 \quad ft.kips/\ ft$

Load Combinations:

Thermal gradient loading [i.e., negative thermal gradient (NTG) and positive thermal gradient (PTG)] and live load need to be combined to create critical load combinations.

Service I-NTG: 1.0 Live Load + 0.5 Negative Thermal Gradient
Service I-PTG: 1.0 Positive Thermal Gradient

Service I-NTG Load Combination:

$M_a = -56.6 + 0.5 \times -17.7 = -65.5 \quad ft.kips = -10.35\, ft.kips/\ ft$

Service I-PTG Load Combination:

$M_a = 59.1 \quad ft.kips = 9.34\, ft.kips/\ ft$

Cracking Moment:

Using AASHTO LRFD section 5.4.2.6 and 5.7.3.6.2

f_r =536 psi ($0.24\sqrt{f_c}', ksi$) and $M_{cr} = f_r I_g / y$ =7.2 *ft-kips / ft*

$M_a > M_{cr}$ *Slab will crack. In that case relief cut is required.*

Negative Moment Reinforcement (i.e., top fiber in tension)

Based on allowable stress limit in the reinforcement per AASHTO LRFD section 5.7.3.4, and assuming d = 6.7 inches, an area of steel of 0.793in.^{2} /ft is required for a moment of -10.35*ft-kips/ft*.

Use #6 bars @ 6 inches = $A_{steel} = 0.88 \quad in^2 > 0.793 \quad in^2$

$f_{steel} = 22.7 \quad ksi < f_{allowable} = 32.4 \quad ksi \;\; z = 91 < 130$

<u>Positive Moment Reinforcement (i.e., bottom fiber in tension)</u>

Based on allowable stress limit in the reinforcement per AASHTO LRFD section 5.7.3.4 and assuming d=6.7 inches, an area of steel of 0.715 in.^{2} /ft is required for a moment of 9.34 *ft-kips/ft*.

Use #6 bars @ 6 inches = $A_{steel} = 0.88 \quad in^2 > 0.715 \quad in^2$

$f_{steel} = 20.5 \quad ksi < f_{allowable} = 32.4 \quad ksi \;\; z = 83 < 130$

DESIGN AXIAL LOAD

For RHHR boundary condition, axial force in the link slab needs to be calculated using the maximum negative moment at the interior support of a two-span continuous system. HL-93 (AASHTO LRFD 2004) loading is applied at both spans to create maximum negative moment of -724 ft. kips at the interior support.

Axial force acting on the link slab due to HL-93 loading:

$$T = \frac{M_{continuity}}{h} = \frac{-724 \times 12}{(54-9/2)} = -176\ kips = -27.8\ kips/ft \qquad \text{(Tension)}$$

Axial force acting on the link slab due to positive temperature gradient:

$$M_{continuity} = \frac{(F_2 d_{tg} - M_3)(3E_{Composite} I_{Composite})}{2E_{Girder} I_{Girder}} = \frac{(32.89 \times 24.73 + 3.61)(3 \times 4031 \times 392892)}{2 \times 4031 \times 125390} = 3840 \quad in.kips$$

$$T = \frac{M_{continuity}}{h} = \frac{3840}{(54-9/2)} = 78 \quad kips = 12.3 kips / \; ft \qquad \text{(Compression)}$$

Axial force acting on the link slab due to negative temperature gradient:

$$T_{NG} = -0.3 T_{PG} = -0.3 \times 78 = 23.4\ kips = -3.7\ kips/ft \qquad \text{(Tension)}$$

DESIGN LOAD COMBINATIONS

Service I-NTG Load Combination:

$$M_a = -10.35\, ft.kips / \; ft \quad (N = 27.8 + 3.7/2 = 29.7 \quad kips / \; ft \quad for \quad RHHR)$$

Service I-PTG Load Combination:

$$M_a = 9.34\, ft.kips / ft \quad (N = -12.32 kips / ft \quad for \quad RHHR)$$

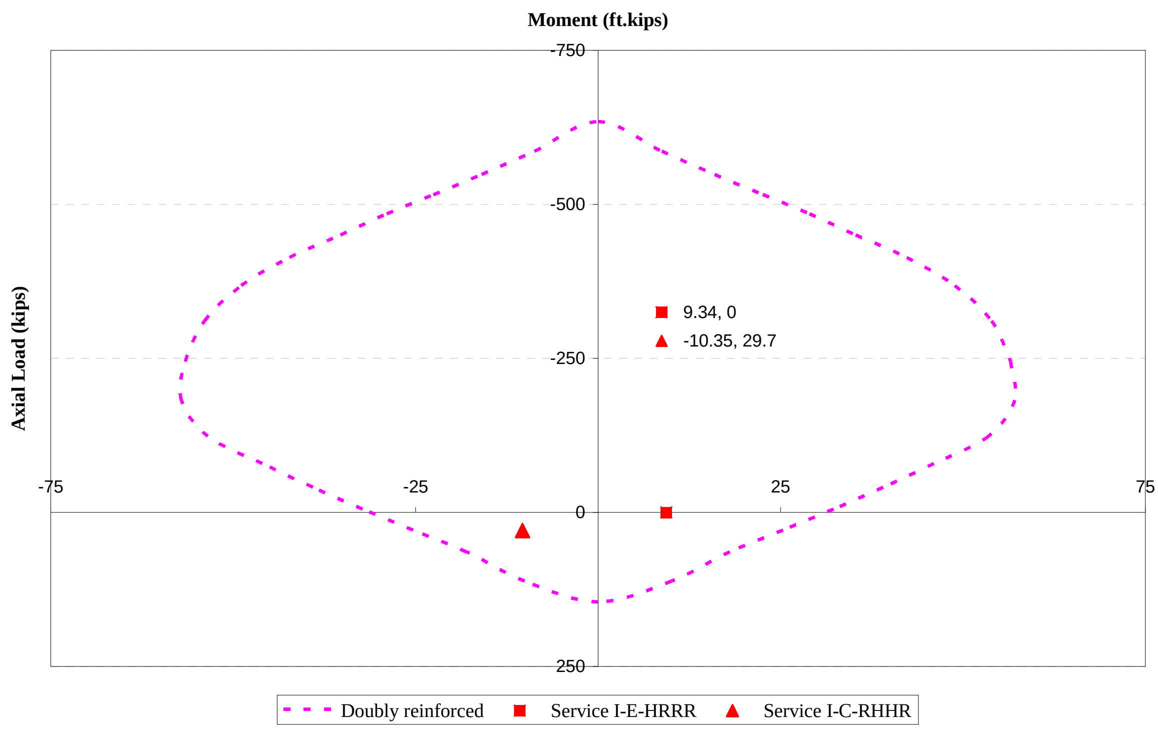


Figure F-6. Moment and Interaction Diagram under Service Loads for unit link slab width

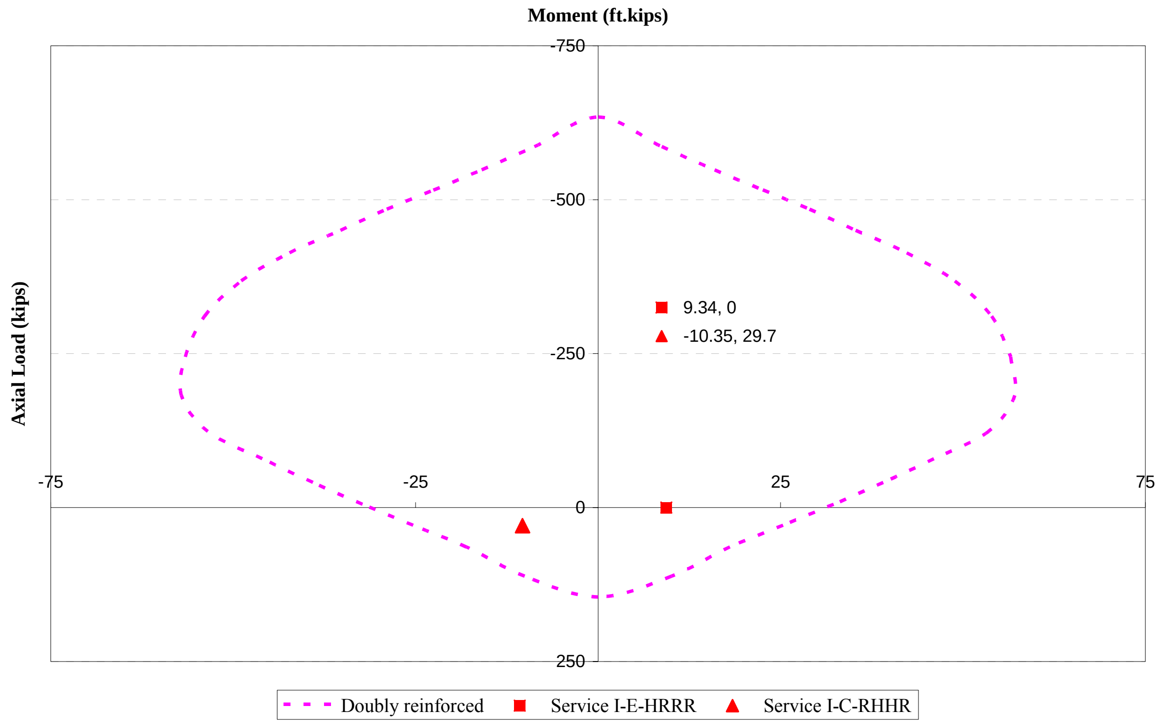
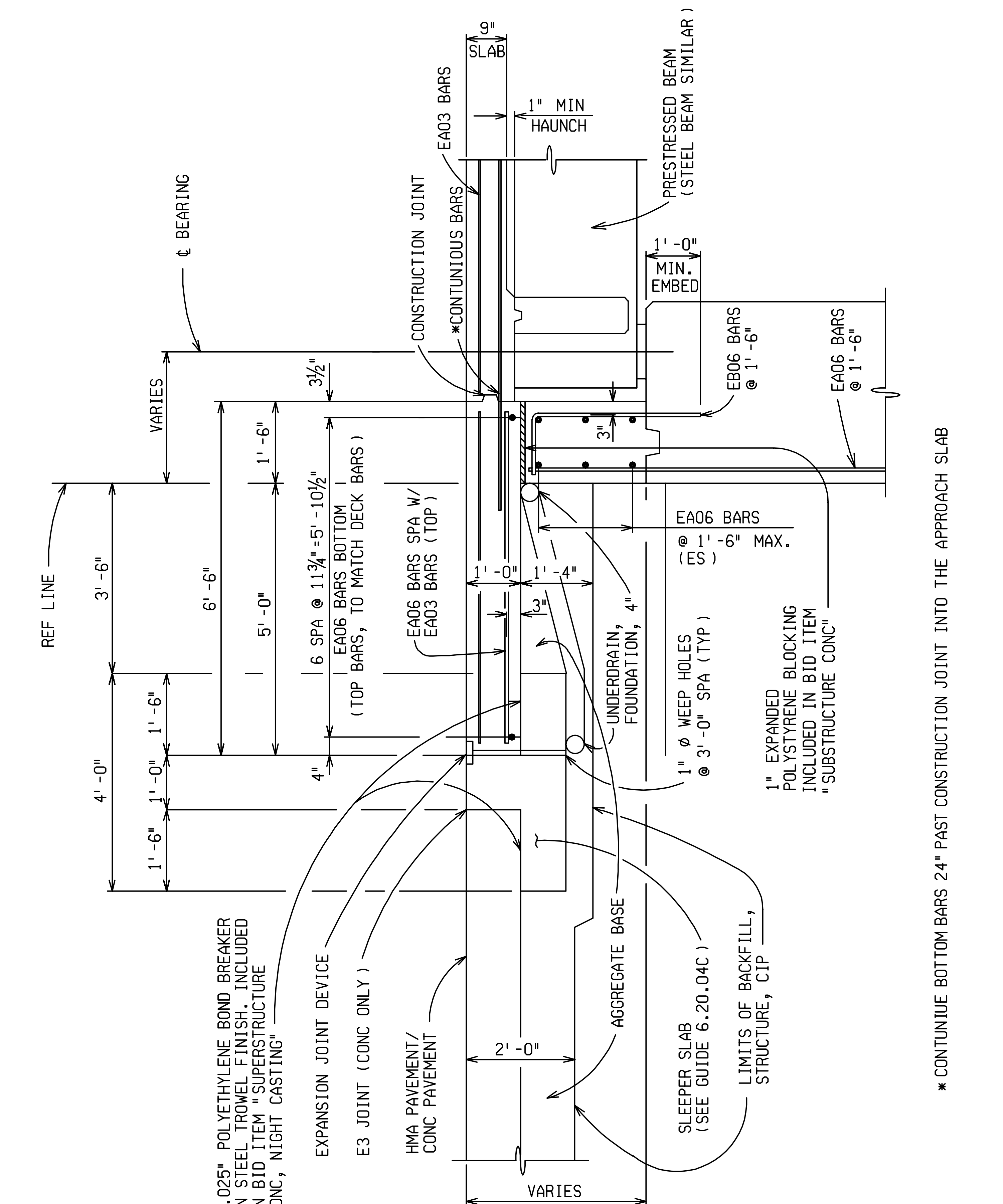


Figure F-6. Moment and Interaction Diagram under Service Loads for unit link slab width

APPENDIX G

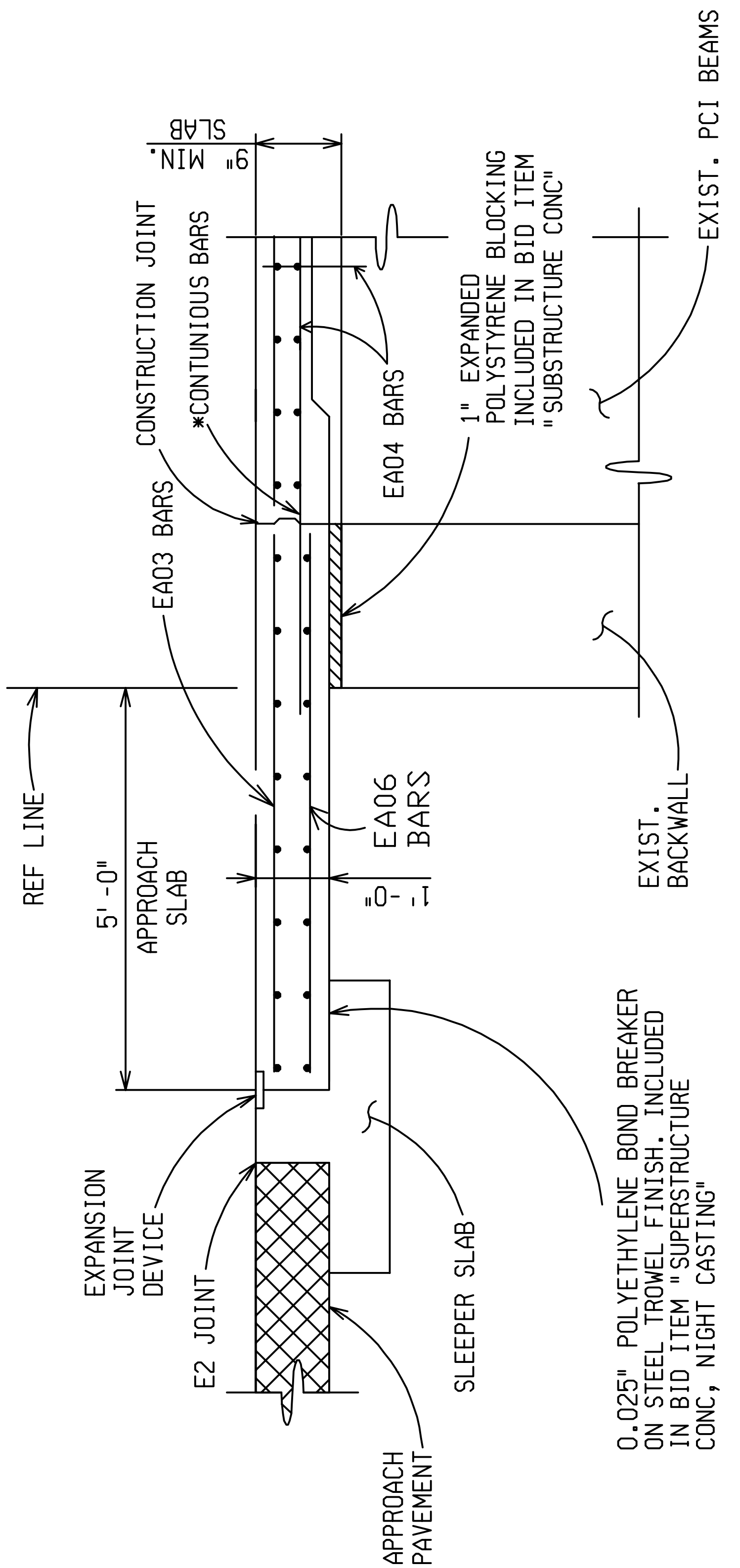
Proposed Design Details in MDOT Design Guide Format

DRAWN BY: CHECKED BY: APPROVED BY:	MICHIGAN DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAY DEVELOPMENT PROPOSED TYPICAL SECTION THRU INDEPENDENT BACKWALL WITH SLIDING SLAB	ISSUED: SUPERSEDES:



PREPARED BY WESTERN MICHIGAN UNIVERSITY	6.20.03XX

DRAWN BY: CHECKED BY: APPROVED BY:	MICHIGAN DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAY DEVELOPMENT PROPOSED TYPICAL SECTION THRU DEPENDENT BACKWALL FOR RETROFIT	ISSUED: SUPERSEDES:



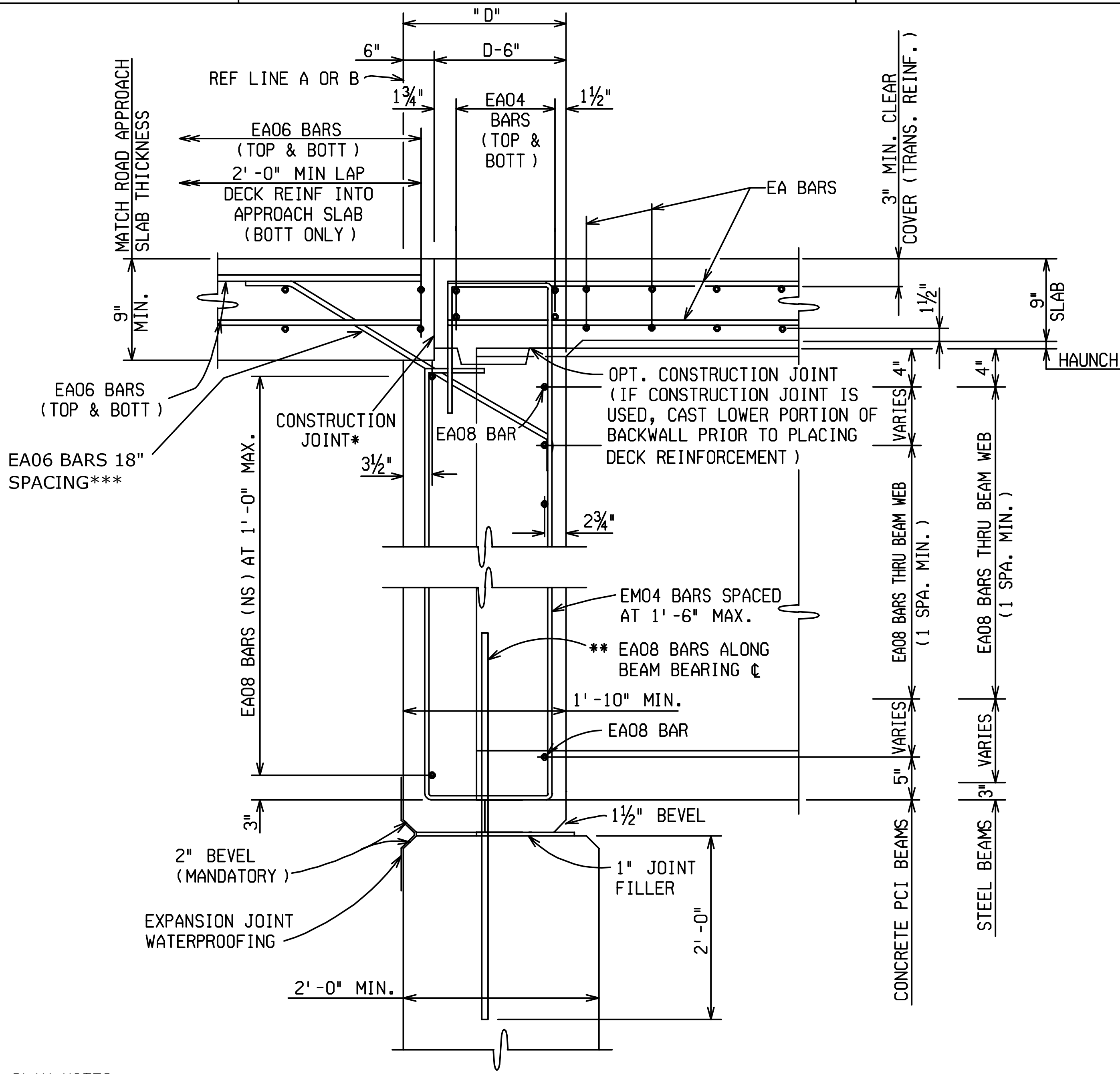
TYPICAL SECTION AT BRIDGE APPROACH

* CONTUNIUE BOTTOM BARS 24" PAST CONSTRUCTION JOINT INTO THE APPROACH SLAB

PREPARED BY WESTERN MICHIGAN UNIVERSITY

6.20.04XX

DRAWN BY: CHECKED BY: APPROVED BY:	MICHIGAN DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAY DEVELOPMENT PROPOSED INTEGRAL AND SEMI-INTEGRAL ABUTMENT BACKWALL	ISSUED: SUPERSEDES:



PLAN NOTES:

* WHERE CONSTRUCTION JOINTS ARE USED, THERE WILL BE NO PAYMENT FOR THE REQUIRED JOINT WATERPROOFING.

NOTES:

INTEGRAL AND SEMI-INTERGRAL ABUTMENT BRIDGES SHALL BE CONSIDERED FOR STEEL BRIDGES LESS THAN 300' AND CONCRETE BRIDGES LESS THAN 400' IN LENGTH.

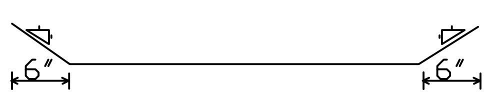
APPROACH SLAB THICKNESS WILL MATCH THE ROAD APPROACH THICKNESS (9" MIN.)

** USE FOR INTEGRAL ABUTMENT BRIDGES ONLY.

SEMI-INTERGRAL ABUTMENTS SHOULD BE USED AT STREAM CROSSINGS.

D = BACKWALL THICKNESS. SEE GUIDE 6.20.01 FOR DEFINITION.

*** EA06 BAR



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